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THE CONTRACT TRIALS OF THE U. S. GUNBOATS *WHEELING* AND *MARIETTA*.

BY PASSED ASSISTANT ENGINEER F. C. BIEG, U. S. NAVY.

The composite twin screw gunboats *Wheeling* and *Marietta*, formerly known as Gunboats 14 and 15, respectively, were built by the Union Iron Works of San Francisco, California, on the plans of the Navy Department. The hulls conform to the Department design, but the propelling machinery was changed in the following respects. Instead of open framing for the main engines, cast steel bed plates and a single condenser for the two engines, composition bed plates, with which were cast the back engine columns and a condenser for each engine, were substituted. In the *Wheeling*, the Howden system of forced draft was substituted for the ordinary ash pit draft, and the grate bars were shortened. In the *Marietta*, two Babcock & Wilcox boilers of the marine type, with ash pit draft, were substituted for the cylindrical boilers.

The contract price, without armament, of the *Wheeling* was $219,000, and of the *Marietta*, $223,000.

These vessels are as alike in hull and engine dimensions as they can be built. Both were launched on March 18, 1897.

The hull framing is of steel. The under water body is planked with Oregon pine to well above the water line; above this, the skin of the vessel is of steel. A steel skin and double bottom are worked amidship, at the side of and under the machinery compartments. The spar and gun decks are continuous; the berth deck stops at the machinery compartment. The bunkers are arranged to afford coal protection to the machinery.

The contract speed was 12 knots, to be maintained for four consecutive hours.

The battery consists of two 4-inch rapid fire guns mounted on the spar deck, one forward and the other aft; two 1-pounder rapid fire guns, one in each gangway; four 4-inch and four 6-pounder rapid fire guns mounted on the gun deck.

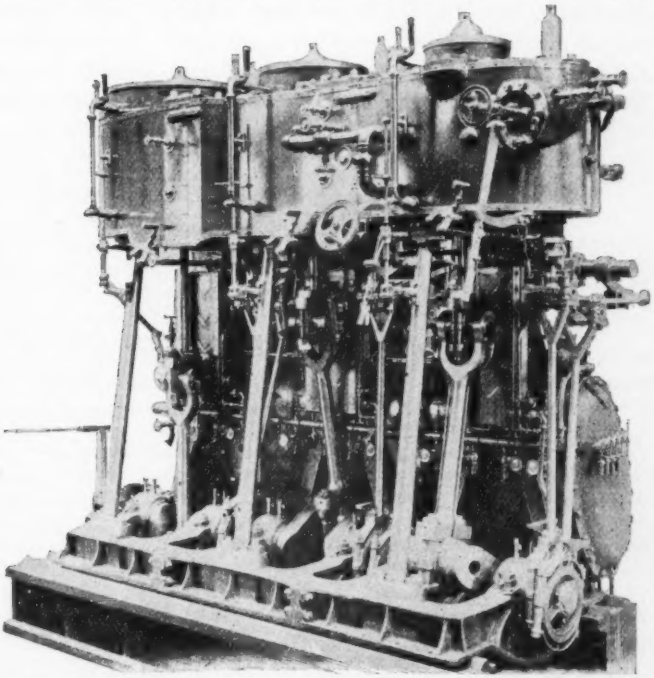
Steam capstans, winches, steering engines and ventilating engines are provided.

HULL.

Length between perpendiculars, feet and inches	174–0¾
on L.W.L. (12 feet), feet and inches	174–0¾
over all, feet and inches	189–6¾
Beam, extreme, feet	34
Ratio of length to beam	5.12 to 1
Depth at side, from keel to top of main deck beam, feet and inches	22–7¾
Draught, mean, normal, sea-going trim, feet	12
Trim	0
Displacement, normal, tons	996
tons per inch L.W.L.	10.13
Area immersed midship section, L.W.L., square feet	338
L.W.L. plane, square feet	4,284
Block co-efficient for displacement	.508
Cylindrical co-efficient for displacement	.592
Midship section co-efficient	.858
L.W.L. co-efficient	.724
Wetted surface to L.W.L., square feet	6,495
Number of frames	105
water tight compartments below main deck and including double bottom	42

ENGINES.

The twin screw engines are of the vertical, inverted, direct-acting, three cylinder, triple expansion type, the governing dimensions of which follow the Department design. They are placed in one compartment with the H.P. cylinders forward. The cranks are 120 degrees apart and follow in the order H.P., I.P.



TRIPLE EXPANSION ENGINES OF GUNBOATS "MARIETTA" AND 'WHEELING."

and L.P. The barrels of all cylinders are jacketed, the jacket of the H.P. cylinder being an enlargement of the H.P. valve chest. Working liners are fitted to all cylinders. Each H.P. cylinder has one piston valve, without packing rings. Each I.P. cylinder has one slide valve of the Allen or Trick type, provided with a balance ring which is connected at the back with the L.P. valve

chest. Each L.P. cylinder has one double-ported slide valve, unbalanced. Double bar Stephenson links of the ordinary type are fitted.

The engines were designed to develop 800 indicated horse power when running at 200 revolutions and with 180 pounds of steam in the boilers. The cylinders are supported at their backs by composition columns cast with the condensers and bed plates, and at their fronts, by forged steel columns. The bed plates and condensers are cast in three sections and bolted together. The crank and thrust shafts and the forward sections of propeller shafts are solid; the after section of each propeller shaft has an axial hole.

The following are some of the principal engine dimensions.

DATA OF ONE MAIN ENGINE.

Number of cylinders	3
Diameter of cylinders, inches, H.P	12
I.P	18
L.P	28
Stroke, inches	18
Diameter of H.P. valve, inches	$7\frac{1}{8}$
Width and height of I.P. valve, inches	$23\text{–}12\frac{9}{16}$
L.P. valve, inches	$32\text{–}19\frac{1}{16}$
Diameter of piston rods (all), inches	$2\frac{1}{2}$
Length of connecting rods, center to center, inches	40
Distance between centers of cylinders, H.P. to I.P., feet	3
I.P. to L.P., feet	3.25
Volume swept by pistons per stroke, cubic feet, mean, H.P.	1.15
I.P.	2.62
L.P	6.83
Volumetric clearance, mean of two ends, cubic feet, H.P.	.21
I.P.	.36
L.P	.78
Ratios of net areas of pistons, H.P. to I.P.	2.28
I.P. to L.P.	2.6
H.P. to L.P.	5.93
Crank shaft, length, feet and inches	$9\text{–}6\frac{1}{2}$
diameter, inches	$5\frac{1}{2}$
length of each bearing, inches	$8\frac{1}{4}$
axial hole, through crank pin only, diameter, inches	$2\frac{1}{2}$
Propeller shaft, forward section, length, feet and inches	$24\text{–}11\frac{5}{8}$
after section, length, feet and inches	$24\text{–}4\frac{7}{8}$
diameter of forward section, solid, inches	$5\frac{1}{4}$
diameter and axial hole of after section, inches	$5\frac{3}{4}\text{–}3$

Thrust shaft, diameter, inches	5¼
collars, number	5
diameter, inches	10
thickness, inches	1¼

PROPELLERS.

The propellers are three-bladed, solid and of manganese bronze. The starboard propeller is left, and the port, right-handed.

Number of blades	3
Diameter, feet and inches	6–9
of hub, inches	14
Length of hub, inches	13
Thickness of blade at center of hub, inches	3¼
Helicoidal area, square feet, one propeller	17
Pitch, true screw, feet and inches	7–3
Ratio of pitch to diameter	1.074 to 1
Distance of center of hub above lowest point of keel, feet and inches	4–8

CONDENSERS.

The main condenser for each engine is cast of composition in three sections, and is oval in shape. The circulating water passes through the tubes.

Number of tubes in one condenser	404
Length of tubes, feet and inches	8–6
Diameter of tubes, outside, inch	⅝
Cooling surface, one condenser, square feet	552
Thickness of tubes, No. 18, B.W.G., inch	.049
Ratio of total cooling surface to total heating surface, *Wheeling*	1 to 2.27
Marietta	1 to 3.31

Auxiliary Condenser.—There is one auxiliary condenser with cylindrical shell. It is fitted with a Dow combined air and circulating pump with vertical cylinders. This condenser is 4 feet 7 inches long and 18 inches in diameter, and has a cooling surface of 150 square feet.

Air Pumps.—There is an air pump for each main engine, driven by a rock shaft and arms from the I.P. crosshead.

Diameter of pump cylinder, inches	10¾
Stroke, inches	9½

Circulating Pumps. — There is one centrifugal circulating pump to each main engine, operated by a compound engine. The pumps have the usual connections to sea, main drain pipes, engine room bilge and overboard discharge.

Diameter of H.P. cylinder, inches	3½
L.P. cylinder, inches	6
Stroke, inches	6
Diameter of runner, inches	18
suction pipe, inches	5
discharge pipe, inches	5

Auxiliary Pumps.—The independent pumps are of the Dow pattern with single vertical steam cylinders. In the engine room there are one main feed pump, one fire and bilge pump and one engine room auxiliary pump. In the fire room there is one auxiliary feed pump.

The main feed and the engine room auxiliary pumps have steam cylinders 6½, and water cylinders 4⅜ inches in diameter, and a stroke of 10 inches. The fire and bilge pump has a steam cylinder 8, and a water cylinder 5 inches in diameter, and a stroke of 10 inches. The auxiliary feed pump has a steam cylinder 10, and a water cylinder 6⅛ inches in diameter, and a stroke of 12 inches.

In addition to the above independent pumps, there are fitted to each main engine, and worked from the air pump crosshead, one bilge pump and one sanitary pump. They are plunger pumps, the plunger being 1⅜ inches in diameter and having a stroke of 9½ inches.

Distilling Apparatus.—This consists of an evaporator with straight horizontal tubes, connecting with a common chamber at their back ends, and drained by four tubes at the bottom. The evaporator has a tube surface of 108 square feet. There are two double coil distillers, with casings of cast iron in halves and bolted together. The coils are of brass. The area of the coils of one distiller is 26.11 square feet. The maximum capacity of the plant is 3,000 gallons of fresh water per 24 hours.

Ash Hoists.—There is one ash hoisting engine of the Union Iron Works type.

Forced Draft.—The forced draft is supplied by two 42-inch blowers of the Union Iron Works type. These draw air from the fire room and deliver it into ducts which, in the case of the *Wheeling*, lead to the Howden system, and in that of the *Marietta*, to the ash pits.

The fans are driven by enclosed compound engines with cylinders $2\frac{3}{4}$ and $4\frac{1}{2}$ inches in diameter and a stroke of 4 inches. The cranks are 180 degrees apart, one eccentric and rod operating a valve that distributes steam to both cylinders.

The Howden system is too well known to require a detailed description. In its application to the *Wheeling*, wrought iron has been substituted for cast iron where possible, in order to lighten the work.

The following particulars of this system, for one boiler, may be of interest.

Air heating tubes (No. 12, B.W.G.), number	229
Length between sheets, inches	31
Diameter, inches	$2\frac{1}{2}$
Tube air heating surface, square feet	387.1
Area for admission of air above grates, square inches	70
below grates, square inches	324
of blower duct, square inches	280

Electric Plant.—There are two compound engines, (cylinder diameters 4 and 6 inches, and stroke 4 inches,) running at 500 revolutions per minute, each of which operates a Siemens and Halske 4-pole generator of 4-kilowatt capacity at 80 volts and 50 amperes. There are 140 outlets for 16 candle power lamps. No search lights are fitted.

BOILERS OF THE *WHEELING*.

There are two single-ended, horizontal, cylindrical, steel boilers, with two furnaces each. They are built of two courses of two sheets each. The front and back heads are curved at the top.

DATA FOR ONE BOILER.

Shell, length over heads, feet and inches	10–6
diameter, mean, feet and inches	10–6
thickness, inch	1

Furnaces, number	2
diameter (least inside), inches	36
(greatest outside), inches	$40\frac{9}{16}$
thickness, inch	$\frac{17}{32}$
length of grate, feet	5
Tubes, number of ordinary, No. 9, B.W.G	130
stay, No. 6, B.W.G	64
diameter all tubes, outside, inches	$2\frac{3}{4}$
length between tube sheets, inches	90
internal diameter, ordinary, inches	2.45
stay, inches	2.34
Thickness of tube sheets, inch	$\frac{3}{4}$
heads, top, inch	$\frac{7}{8}$
bottom, inch	$\frac{3}{4}$
Tube heating surface, square feet	1,047.6
Plate heating surface, furnaces, square feet	82.06
combustion chambers, square feet	82.00
tube plates, square feet	42.56
Total heating surface, square feet	1,254.22
Grate surface, square feet	30
Area through tubes, square feet	6.17

TOTALS FOR TWO BOILERS.

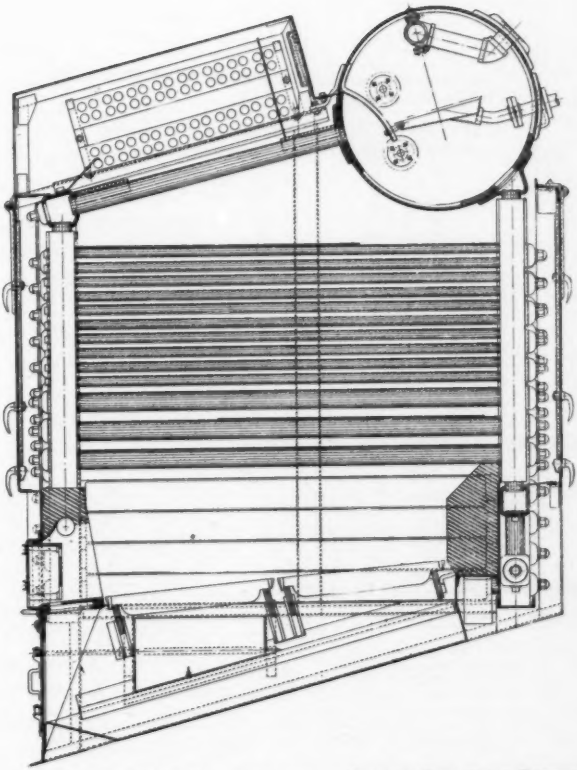
Heating surface, square feet	2,508.44
Grate surface, square feet	60
Area through tubes, square feet	12.34
Net area of smoke pipe, square feet	14.2
Height of smoke pipe above grate, feet	60.66
Ratio of H.S. to G.S.	41.3
area through tubes to grate surface	1 to 4.86

BOILERS OF THE *MARIETTA*.

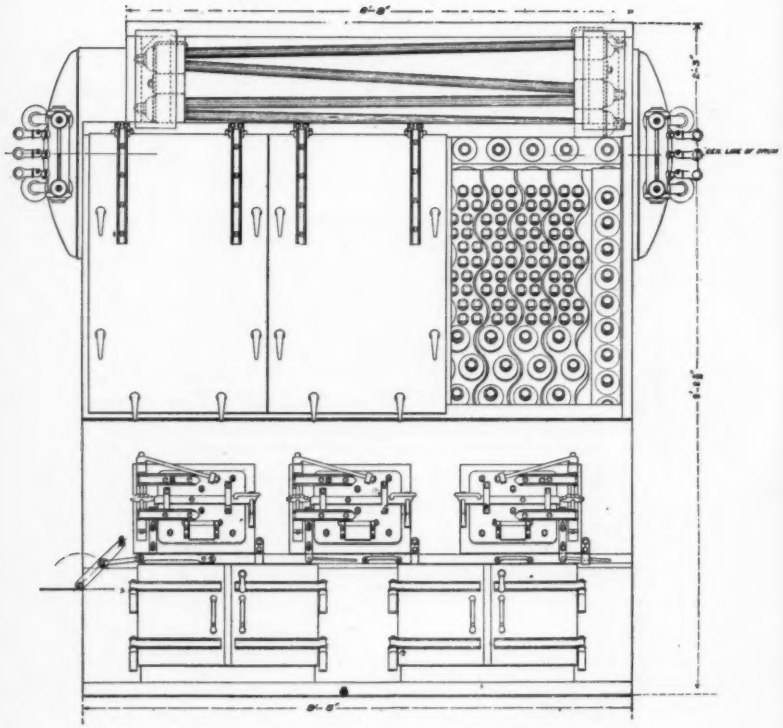
The original design called for two cylindrical boilers of the same size and kind as those installed in the *Wheeling*, but at the request of the contractors, two Babcock and Wilcox water tube boilers of the marine type were substituted. As installed on the *Marietta*, the boiler is shown in the cuts.*

Each boiler consists of banks of straight tubes, placed at an inclination of 15 degrees to the horizontal, and expanded at their ends into wrought steel sinuous headers, $\frac{1}{2}$ inch thick. Mounted in the triangular space formed above the tubes is a

*As the *Marietta's* boilers are the same as those in the *Annapolis*, described on page 565 of the August number, the cuts will apply to both vessels.—EDIT.



BAFFLE PLATES ON TOP ROW AND ON SECOND ROW FROM BOTTOM.



steam and water drum. The headers are connected to this drum by 4-inch nipples or tubes expanded into bored holes. At the lowest corner of the bank of inclined tubes is placed a blow-off connection or sediment chamber which permits every part of the boiler to be thoroughly drained. The first three rows of tubes over the fire are 4, and the ten rows above these, 2 inches in diameter.

The furnace sides are constructed of square boxes made of $\frac{5}{8}$-inch open-hearth steel expanded into straight, open-hearth steel manifolds; one manifold is placed in each corner of the boiler, and the four form pillows which support the boiler, and through which the boiler is bolted to the foundations in the vessel.

Opposite the end of each tube is an opening of sufficient size to permit of its examination and removal when necessary, all cleaning being easily performed through this opening.

Owing to the construction of these boilers, nearly all repairs may be made by the ship's force.

The feed water heater or economizer is a structure entirely separate from the boiler, and the boiler may be operated without using the heater. When the heater is in use, the feed water enters it through the usual check and stop valves and, after passing through the heater, goes by means of a pipe and other check and stop valves to the steam drum. A second feed pipe, connected directly to the drum and independent of the heater, is used when the heater is disconnected.

Two sets of baffle plates, as shown in the cut, are placed over the inclined tubes for the purpose of making the combustion more nearly complete and abstracting more heat from the gases. The vertical baffle plate, shown at the drum end of the feed water heater, is for the purpose of inducing a circulation of water in the heater when lying still, by keeping one end of the heater cool. If the pressure in the heater should become greater than that in the boiler, the heater will discharge into the drum, provided the connection to the drum is open. If this should be closed, the heater will discharge its steam into the atmosphere through a safety valve fitted to the heater.

DATA FOR ONE BOILER.

Length, feet and inches	11–7
Width, over lower part, feet and inches	9–6
steam and water drum, feet and inches	10–9
Height, over all, feet and inches	11–5 5/16
Steam and water drum, internal diameter, inches	42
length over heads, feet and inches	10–9
thickness of shell, inch	19/32
heads, inch	3/4
Furnace, number	1
length, feet and inches	6–1 1/2
width, feet	8
Tubes, length of all, feet	7.5
number of 4-inch	57
thickness, B.W.G. No. 6, inch	.203
number of 2-inch, in boiler only	260
thickness, B.W.G. No. 8, inch	.165
Heating surface in boiler, square feet	1,575
heater, square feet	235
total, square feet	1,810
Grate surface, square feet	49

TOTALS FOR TWO BOILERS.

Heating surface, square feet	3,620
Grate surface, square feet	98
Ratio H.S. to G.S.	37

Coal Bunkers.—The capacites of the coal bunkers, in cubic feet and in tons, at the rate of 42 cubic feet to the ton, are as follows.

Wheeling, 10,395 cubic feet; 247.5 tons.
Marietta, 10,356 " " 246.57 "

Weights.—The following are some of the weights of the machinery, in tons.

	Wheeling.	*Marietta.*
Two main boilers with their fittings and clothing	46.6	43.4
Water, in *Wheeling's* boilers 4 inches above highest heating surface, in *Marietta's* to steaming level	21.8	8
Uptakes	5.9	3.3
Smoke pipe	6.4	6.2
Engines, including bed plates, framing, valves, valve gear, shafting, cylinders, propellers, air pumps and condensers, circulating pumps and their engines	26.8	26.7

The weight of boilers per square foot of heating surface is as follows.

	Wheeling.	*Marietta.*
Weight of boiler per square foot of heating surface, (dry).....	41.6	26.9
(wet).....	61.0	31.8

THE TRIALS.

Previous to the official four hours' trial, the propellers of each vessel were standardized by runs over a measured base of 6,137.5 feet at Bluff Point in San Francisco Bay. The results of these progressive trials are given below. The runs of the *Wheeling*, at low speed, were made during a comparative calm, while those of the *Marietta* were made in a rather fresh breeze. At the higher speeds, the conditions were exactly reversed. The I.H.P. is that of the main engines only; the number of revolutions per minute is the mean for both engines.

PROGRESSIVE SPEED TRIALS U. S. S. *WHEELING*.

Run.	Speed, knots.	Revolutions per minute.	I.H.P.
1	8.719	117	133.12
2	5.893	125	168.76
3	10.919	158	314.44
4	7.956	157	306.9
5	11.506	179	451.93
6	9.469	178	473.06
7	11.086	177	459.99
8	9.989	181	477.04
9	10.242	199	650.82
10	12.582	200	648.94
11	9.989	199	650.06
12	12.713	203	689.77
13	11.292	224	953.89
14	13.825	228	991.38
15	11.654	228	1,022.25
16	13.669	227	1,003.63

Mean of runs.	Speed, knots.	Revolutions per minute.	I.H.P.
1 and 2	7.306	122	150.94
3 and 4	9.437	158	310.67
5, 6, 7 and 8	10.395	179	466.01
9, 10, 11 and 12	11.333	200	654.82
13, 14, 15 and 16	12.674	226	1,003.21

PROGRESSIVE SPEED TRIALS U. S. S. *MARIETTA*.

1	5.568	118	136.89
2	8.062	112	127.90
3	7.074	143	243.30
4	10.10	149	280 06
5	12.452	184	514.62
6	8.89	182	475.83
7	12.242	180	461.27
8	8.906	181	497.78
9	13.126	204	677.81
10	10.789	210	749.73
11	13.080	210	741.44
12	11.222	209	731.30
13	12.452	229	981.55
14	13.367	231	1,024.52
15	12.939	236	1,069.88
16	13.032	231	1,059.01
Mean of			
1 and 2	6.815	115	132.4
3 and 4	8.587	146	261.68
5, 6, 7 and 8	10.594	182	477.96
9, 10, 11 and 12	11.994	208	735.33
13, 14, 15 and 16	13.045	232	1,040.47

The *Marietta* made her official trial on May 26, and the *Wheeling*, on May 29, 1897. The contract speed for the four hours' run was determined from the average revolutions for this time and the curve of speed and revolution obtained from the data of the progressive trials.

The following data give the results of the four hours' trials.

CONTRACT TRIAL DATA.

	Marietta.	*Wheeling.*
Draught, beginning trial, for'd, ft. and ins.	11–9	11–9½
aft, ft. and ins...	12–3	12–4
end of trial, for'd, ft. and ins.....	11–8	11–9
aft, ft. and ins.....	12–2	12–3
mean, for'd, ft. and ins.....	11–8½	11–9¼
aft, ft. and ins.....	12–2½	12–3½
average on trial, ft. and ins.....	11–11½	12–0⅜
Displacement (mean), tons.....	991	1,000
Area of immersed midship section, sq. ft...	349	352
Wetted surface, sq. ft.....	7,250	7,300
Speed, mean, knots.....	13.02	12.88
Slip, mean of both screws, per cent.....	21.5	22.2
Speed^3 × area immersed midship section ÷ I.H.P. (*A*).....	747.8	711.6
Speed^3 × displacement^{⅔} ÷ I.H.P. (*A*)....	213	202.2
I.H.P. (*A*) per 100 sq. ft. wetted surface...	14.2	14.5

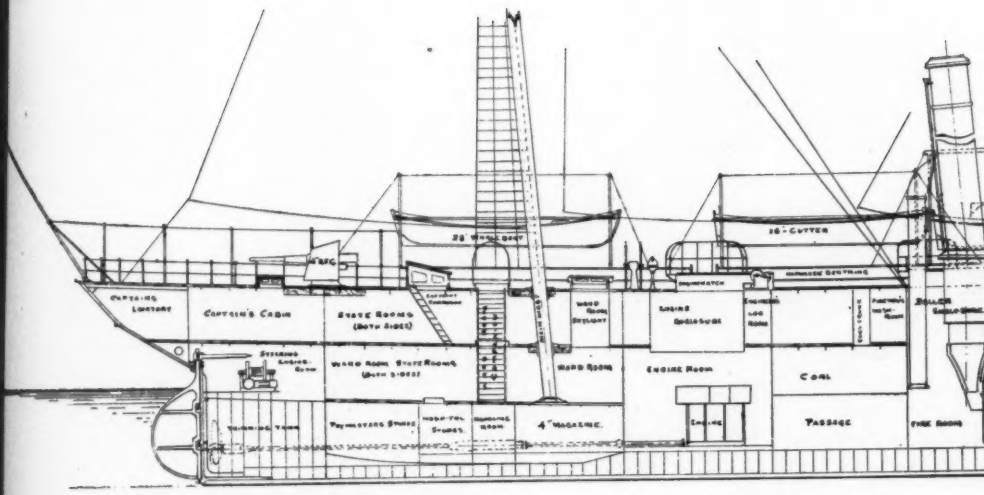
SYNOPSIS OF STEAM LOG.

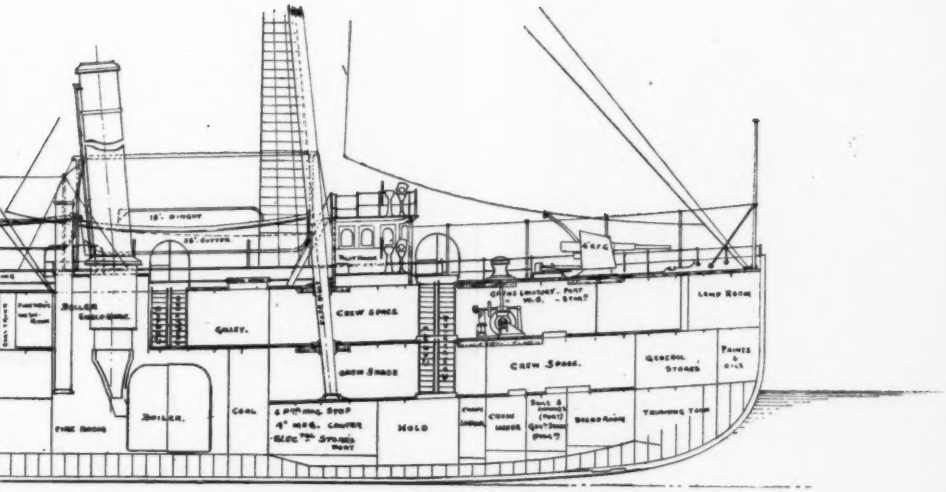
	Starbd.	Port.	Starbd.	Port.
Revolutions main engine, per minute.....	231.1	232.5	230.4	232.4
Piston speed, feet per minute.....	693.3	697.5	691.2	697.2
Steam pressure, in boilers, per gauge.....	173.6		182	
at engine, per gauge.....	171.7	171.5	156.5	157.2
1st receiver, absolute.....	69.4	70.5	71.2	71.1
2d receiver, absolute.....	27.6	25.4	24.7	24.4
Vacuum in condenser, inches.....	26.3	26.2	26.3	27.1
Throttle valve opening.....	wide.		wide.	
Double strokes circulating pump, per minute,	361	357.9	469.	482.8
feed pump, per minute.....	18	18	36	36
Temperature in degrees Fahrenheit:				
Injection.....	70.4		63.5	
Discharge.....	107		95.2	
Feed.....	121		104.2	
Engine room.....	112.4		100.6	
Fire room.....	118.4		96.2	
Uptake.....	850–1,100		553	
Air pressure in ash pits, inch of water.....	.36		.78	
Revolutions of forced draft blowers, average per minute.....	663	716	754	735
Mean pressure in cylinders, H.P.....	64.6	67.15	66.4	67.5
I.P.....	31.7	33.15	35.25	36.52
L.P.....	14.55	14.25	14.05	13.75
Aggregate equivalent pressure referred to L.P. piston.....	39.63	41.37	42.01	43.47

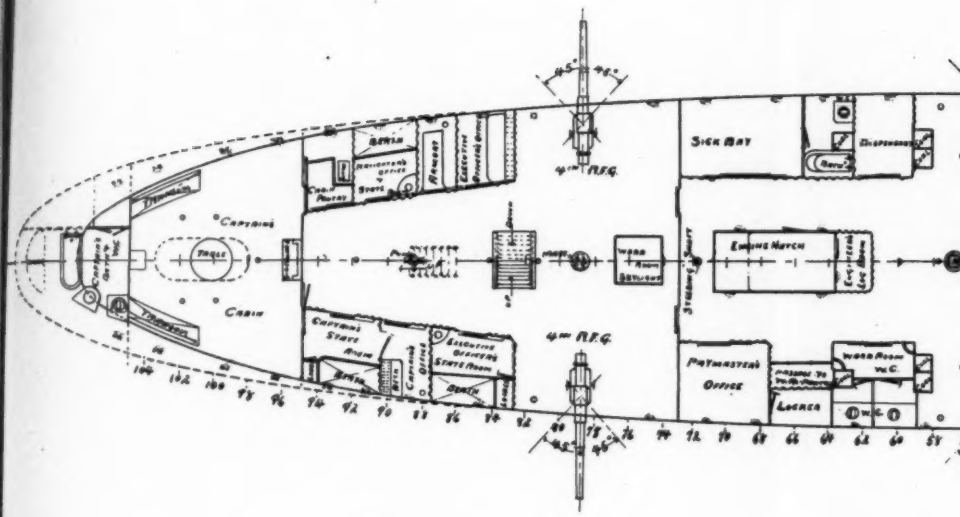
	Marietta.		*Wheeling.*	
I.H.P.:	Starbd.	Port.	Starbd.	Port.
H.P. cylinder	150.25	157.16	153.96	157.89
I.P. cylinder	167.74	176.47	185.94	194.27
L.P. cylinder	187.43	184.69	180.43	178.12
Collective, each main engine	505.42	518.32	520.33	530.28
both main engines	1,023.74		1,050.61	
Circulating pumps	3.16	3.16	3.16	3.16
Main feed pumps	6.08		6.08	
Two forced draft blowers	4.6		4.6	
Other auxiliaries	13.34		12.17	
Collective, main engines and circulating pumps, (*A*)	1,030.06		1,056.93	
Total, all machinery in use	1,054.08		1,079.78	
Indicated thrust (main engines only), pounds	9,954.7	10,147.3	10,239.8	10,385.9
Indicated thrust per square foot of developed blade area, pounds	585.5	596.9	602.3	610.9
Indicated thrust per square inch of thrust bearing	34.99	35.67	36	36.51
Cubic feet swept per minute by L.P. piston per I. H.P.	5.84	5.73	5.66	5.60
Square feet cooling surface per I.H.P. (*A*)	1.07		1.04	
Square feet of H.S. per total I.H.P.	3.48		2.32	
I.H.P. per square foot grate surface, total,	11.2		18.0	
ton machinery (penalty weight),	10.15		9.34	

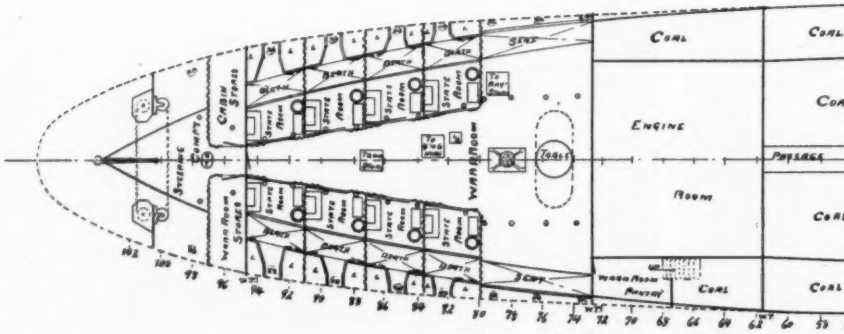
Coal.—The coal consumed was Harris' Navigation, of good quality, and was put up in bags. The quantity consumed per hour on the *Marietta* was 2,300, and per I.H.P. (total) per hour, 2.18 pounds. The figures for the *Wheeling* were 1,855.5 and 1.72, respectively.

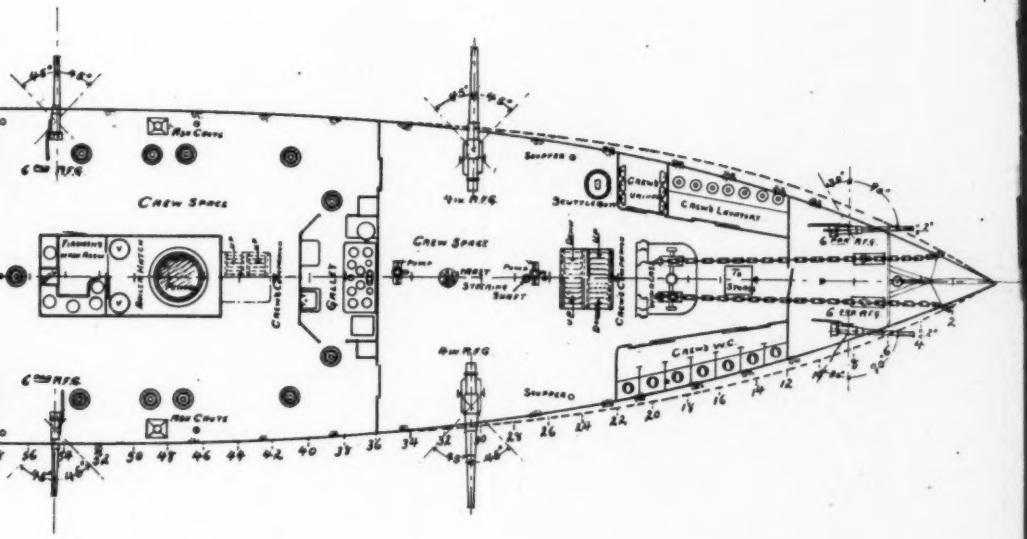
The writer is indebted, for valuable assistance in the preparation of this paper, to P. A. Engineer H. Gage, U. S. N., the Assistant Inspector of Machinery at the Union Iron Works, and to the Babcock & Wilcox Co.

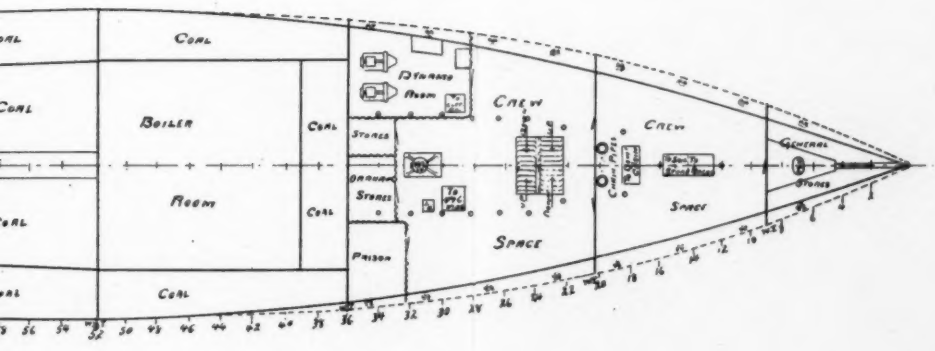

CAPTAIN'S LOOKOUT
CAPTAIN'S CABIN
STATE ROOMS (BOTH SIDES)
WARD ROOM STATE ROOMS (BOTH SIDES)
WARD ROOM
ENGINE ROOM
COAL
PASSAGE
4" MAGAZINE
16-CUTTER


16' DINGHY
25' CUTTER
GALLEY
CREW SPACE
CREW SPACE
CREW SPACE
LAMP ROOM
GENERAL STORES
PAINTS & OILS
BOILER
COAL
HOLD
BOILER ROOM
TRIMMING TANK

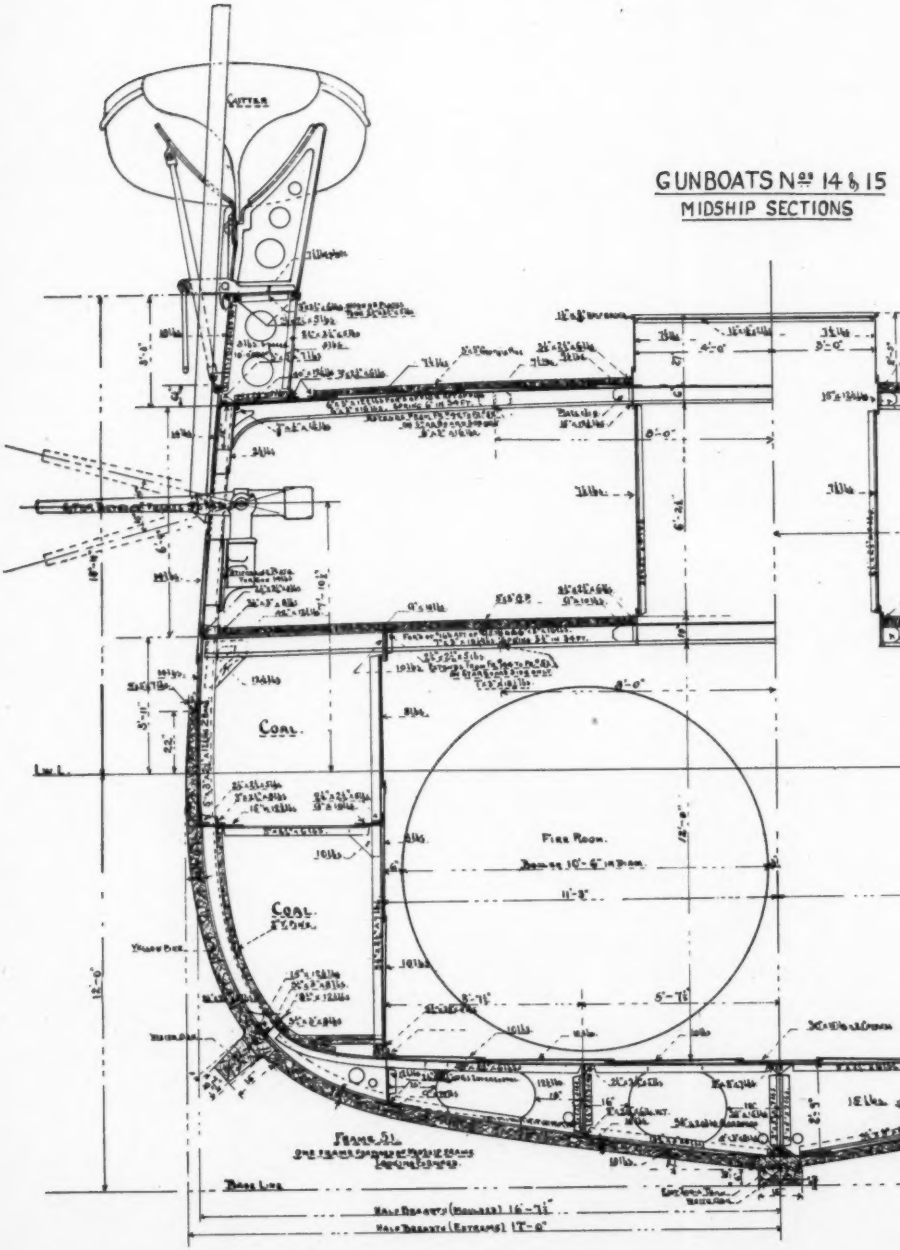

Sick Bay
Engine Hatch
Cabin
Captains State Room
Executive Officers State Room
Paymasters Office
Lockers
Ward Room W.C.
4" R.F.G.


Coal
Engine Room
Cabin Stores
Ward Room Stores
Ward Room
Steering Gear
Torpedo

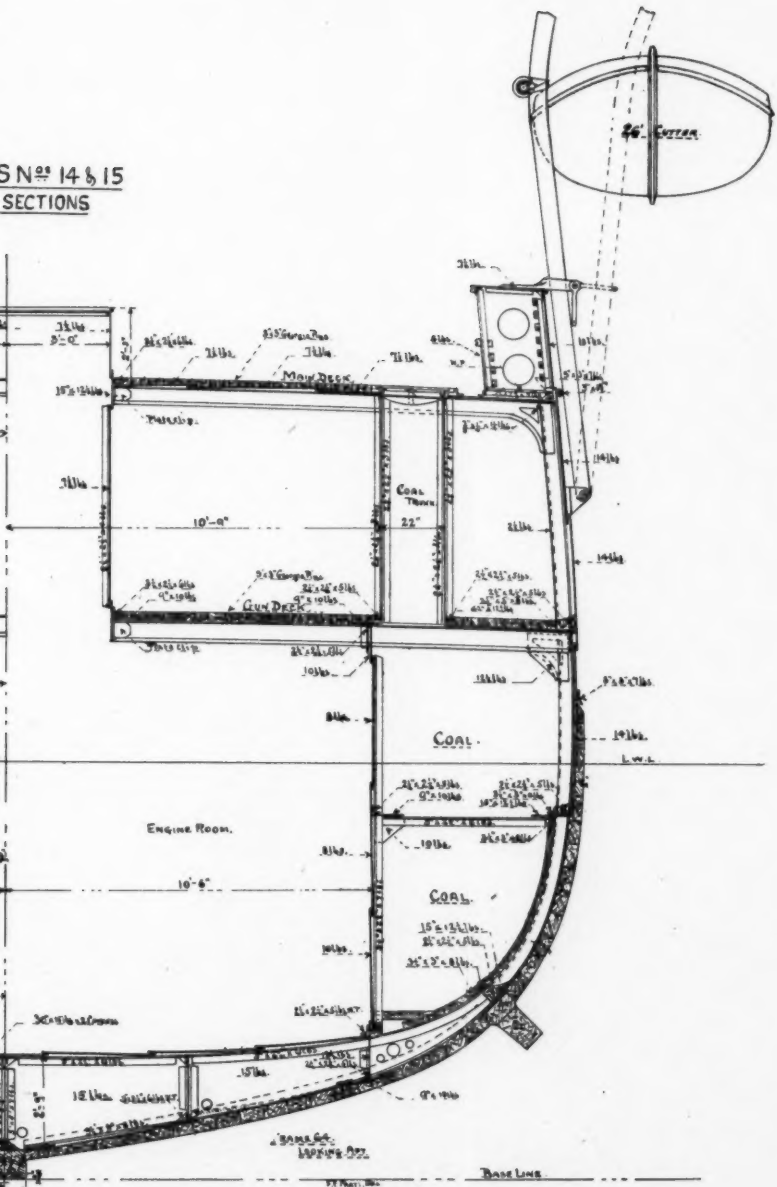

6 CSM R.F.G.
Crew Space
Gallery
4 in R.F.G.
Crew Space
Crew Lavatory
6 CSM R.F.G.
6 CSM R.F.G.
4in R.F.G.
Crew W.C.
6 CSM R.F.G.


Coal
Coal
Boiler
Room
Coal
Coal
Stores
Provision Stores
Prison
Coal
Coal
Stores
Crew
Space
Crew
Space
Generator
Stores

GUNBOATS Nos 14 & 15
MIDSHIP SECTIONS



S Nos 14 & 15
SECTIONS



THE CONTRACT TRIAL OF THE U. S. TORPEDO BOAT *FOOTE*.

By Passed Assistant Engineer C. N. Offley, U. S. N.

This steel, twin screw, sea-going torpedo boat, built by the Columbian Iron Works and Dry Dock Company at Baltimore, Md., was launched October 1, 1896.

The general designs and specifications were furnished by the Navy Department. The contract price was $97,500, and a speed of 24½ knots, maintained for a period of two consecutive hours, being guaranteed, the vessel to carry the torpedoes and torpedo gear, rapid firing guns and ammunition, coal, crew, boats, anchors, electric plant, equipment, &c., besides the weight of the complete hull, machinery and spare parts. The total of these trial weights amounts to 24.7 tons. The contract carried a penalty at the rate of $10,000 a mile, should the guaranteed speed of 24½ knots not be developed, provided the speed did not fall below an average of 23 knots. Should the speed be less than 23 knots, the contract left it optional with the Secretary of the Navy to reject the boat, or to accept her at a reduced price to be agreed upon.

The boat is divided into thirteen main water tight compartments by thwartship bulkheads, and the coal bunkers form eight other water tight compartments, making twenty-one compartments in all. The quarters for the officers are situated in the forward part of the boat, while the petty officers and crew are located aft.

The coal bunkers are arranged outboard of the boiler and engine compartments, and hold 44 tons of coal.

There are two conning towers, the steam steering engine being placed in the forward, and the hand steering gear, in the after

tower. The engine room telegraphs are arranged to be worked from either conning tower.

Three torpedo launching tubes are carried on deck, one on either side just abaft the forward conning tower, and one aft, amidships. All three tubes are mounted on carriages and are trained by hand. Four Whitehead torpedoes are carried, three being stowed in the torpedo tubes, and the fourth, in a case on deck.

There are three one-pounder rapid firing guns.

No search light is fitted.

HULL.

Length between perpendiculars, feet	160
on L.W.L., feet	160
over all, feet and inches	161–7
Beam, extreme, feet and inches	16–1¾
Ratio of length to beam	9.9
Depth, top of floors to top of deck beams, feet and inches	9–10½
Draught, mean (normal), feet and inches	4–10½
Trim, feet and inches	forward 4–3½; aft 5–4½
Displacement (normal), tons	137
Tons per inch, L.W.L.	4.3
Area immersed midship section, L.W.L., square feet	57
L.W.L. plane, square feet	1,790
Center of gravity of L.W.L. from frame 53, feet	10
buoyancy above bottom of keel plate, feet	3.63
abaft frame 53, feet	2.61
gravity above bottom of keel, feet	5.50
Transverse metacenter above center of buoyancy (B.M.), feet	4.54
Longitudinal metacenter above center of buoyancy (B.M.), feet	403.38
Transverse G.M., feet	2.59
Longitudinal G.M., feet	401.68
Block coefficient for displacement	.396
Midship section coefficient	.7375
L.W.L. coefficient	.677
Wetted surface to L.W.L., square feet	2,730
Number of frames	104
compartments, including bunkers	21

MAIN ENGINES.

There are twin screw engines of the vertical, inverted, direct-acting, four-cylinder, triple expansion type; the general design having been made by the Bureau of Steam Engineering, and the de-

tails worked out by the contractors, subject to the approval of the Bureau. They are placed in separate water tight compartments, the starboard engine being forward and the port engine aft. The high pressure cylinder is aft in the starboard, and forward in the port engine room. The high and intermediate pressure cranks are opposite each other, and the two low pressure cranks are similarly placed with regard to each other. The high and intermediate pressure cranks make an angle of 90 degrees with the first and second low pressure cranks. The sequence is thus: high pressure, second low pressure, intermediate pressure and first low pressure. The cylinders are not steam-jacketed, but are well lagged with magnesia and covered with Russia iron, finished with bright brass bands. Each high pressure cylinder has one, and each intermediate pressure and each low pressure cylinder, two piston valves. The valves are worked by an independent valve crank shaft, parallel to the main crank shaft, and geared to it so as to make equal revolutions with, but in the opposite direction to it. The main engines were designed to develop 2,000 I.H.P., when running at about 412 revolutions per minute, with a steam pressure of 250 pounds per square inch in the boilers.

The framing of the engines consists of wrought steel columns, stiffened by wrought steel ties. The framing is also tied to the hull of the ship to prevent vibration of the engines. The bed plate consists of a single $\frac{5}{8}$-inch steel plate, cut out for the swing of the cranks. It is supported on the foundation built in the boat by cast iron distance pieces about one inch thick, through which the foundation bolts pass. Between the cast iron pieces are wood filling pieces. The main bearing pillow blocks are of cast steel and support the lower ends of the columns of the framing. The crosshead guides are of bronze, cored out for water circulation, and are carried by lugs on the cylinder casings, and are further supported by a fore-and-aft wrought steel beam which forms part of the framing.

The piston rods and valve stems are oil-tempered and ground true. The piston and connecting rods are bored out axially to reduce the weight of the reciprocating parts.

The pistons are of cast steel fitted with hard cast iron packing rings. All the piston rod and valve stem stuffing boxes are packed with Katzenstein's metallic packing.

The main and auxiliary steam pipes are made of lap-welded iron pipe, fitted with wrought iron flanges; the various pipe branches being grouped and led to manifold brass castings which form a part of the main line of pipe.

There is a separate condenser for each engine.

The following are some of the principal dimensions of the engines.

DATA FOR ONE MAIN ENGINE (STARBOARD).

Number of cylinders	4
Diameter of cylinders, inches, H.P.	12
I.P.	19½
L.P. (2)	22
Stroke, inches	16
Diameter of valves, inches, H.P. (1)	6½
I.P. (2)	7½
L.P. (4)	7½
piston rods (all), outside, inches	2½
inside, inches, H.P. and I.P.	1⅞
L.P. (2)	1⅝
Connecting rods, length center to center, inches	40
diameter, outside, upper end (all), inches	2⅝
lower end (all), inches	2⅝
inside, H.P. and I.P., inches	1⅝
L.P. (2), inches	1⅝
Distance between centers of cylinders, inches, H.P. to I.P.	20½
I.P. to 1st L.P.	27½
1st L.P. to 2d L.P.	26½
Volume swept by piston per stroke, cubic feet, H.P.	1.04
I.P.	2.69
L.P. (both)	7.02
Volumetric cylinder clearance (mean of two ends), cubic feet, H.P.	.172
I.P.	.434
1st L.P.	.526
2d L.P.	.535
Ratios of areas of pistons, H.P. to I.P.	2.57
I.P. to both L.P.	2.61
H.P both to L.P.	6.72
Crank shaft, length over all, feet and inches, starboard	10–0¾
port	9–2¾
diameter, outside, inches	5½
axial hole, inches	3⅜

Crank pins, diameter, outside, inches, (all)	5¼
length, inches, H.P. and I.P.	8½
L.P., each	6½
axial hole, inches, (all)	3⅜
Thrust shafts, length, feet and inches, starboard	21–6
port	11–4½
diameter, (solid), inches	4¾
number of thrust collars	8
thickness of thrust collars, inch	⅝
diameter of thrust collars, inches	7⅞
Stern tube shafts, length, feet and inches	23–6
diameter, (solid), inches	5
Propeller shafts, length, feet and inches	33–7¾
diameter, (solid), inches	5

PROPELLERS.

The propellers are three-bladed true screws, the blades being cast solid with the hub. The material is manganese bronze. The starboard propeller is right, and the port, left-handed, both propellers turning outboard in the ahead motion. The general form of the blades is pear-shaped, the greatest width of blade being about $\frac{5}{10}$ of the radius from the center of the hub. The lowest point of the circle swept by the tips of the blades is about 10 inches below the base line. The after body of the boat is cut away below the water line, giving a free flow of water from forward to the screws.

PROPELLERS.

Number of blades	3
Diameter, feet and inches	5– 2
of hub, inches	10
Length of hub, inches	13
Thickness of blade at center of hub, inches	2⅜
Helicoidal area, one propeller, square feet	9.68
Disc area, one propeller, square feet	20.966
Pitch, feet and inches	7–10
Ratio of pitch to diameter	1.5112 to 1
Distance of center of hub above lowest point of keel, feet and inches	1– 9

CONDENSERS.

The main condenser shell is cylindrical and made of sheet brass in two sections, the sections being riveted to a composition angle ring. The after or outlet head is made of copper; the

forward head is made of composition and forms the casing for the circulating pump. The circulating water passes through the tubes.

DATA OF ONE CONDENSER.

Number of tubes	816
Length between tube sheets, feet	6
Diameter of tubes, outside, inch	$\frac{5}{8}$
Thickness of tubes, B.W.G., No.	20
Cooling surface, square feet	801
Ratio total cooling surface to total heating surface	1 to 3.2834

AIR PUMPS.

There are two double-acting, horizontal air pumps for each engine, worked by eccentrics on the main shafts. Each pump has a cylinder $5\frac{1}{2}$ inches in diameter and a stroke of 5 inches. These pumps are of the type that has become known as the "Bailey" air pump, and described on page 518 of Volume VI.

CIRCULATING PUMP

There is a circulating pump for each condenser. The runner of the pump is a composition screw propeller with four broad blades, and discharges directly into the water chamber of the condenser, which also forms the pump casing. The circulating pump is run by a vertical single-cylinder engine, 4 inches in diameter by 3 inches stroke. The pump is fitted to draw from the sea or from the main drain, and to discharge through the condenser. The diameters of the injection and discharge pipes are $6\frac{3}{4}$ inches. The injection pipes are fitted with a combined strainer and scoop on the bottom of the boat to throw the water through the condenser when the boat is under way.

FEED AND OTHER PUMPS.

There is in each engine room a main feed pump having a $7\frac{1}{2}$-inch steam cylinder, a $4\frac{1}{2}$-inch water cylinder and a stroke of 8 inches. These pumps are of the Blake vertical simplex type. In each fire room there is an auxiliary feed pump having a 6-inch steam cylinder, a 4-inch water cylinder and a stroke of 8 inches. These pumps are of the same type as the main feed

pumps. The main feed pumps have suctions from the feed tanks and hot wells, and discharge into the feed main. The auxiliary feed pumps have suctions from the main drain, the fire and engine room bilges and the sea, as well as from the feed tanks; the suctions are so arranged that it is impossible to draw from more than one direction at any particular time. These pumps have discharges into an auxiliary feed main and overboard; also a connection to the engine water service and to the fire main. There is a steam bilge ejector in each fire and engine room. Each ejector has a capacity of 25 tons per hour.

DISTILLING APPARATUS.

There is in each fire room a vertical Baird evaporator with spiral coils and a rated capacity of 500 gallons per day. There is one distiller, designed by the Bureau of Steam Engineering, in the forward fire room. It has a capacity of 200 gallons of potable water at 90 degrees F. per day.

FORCED DRAFT.

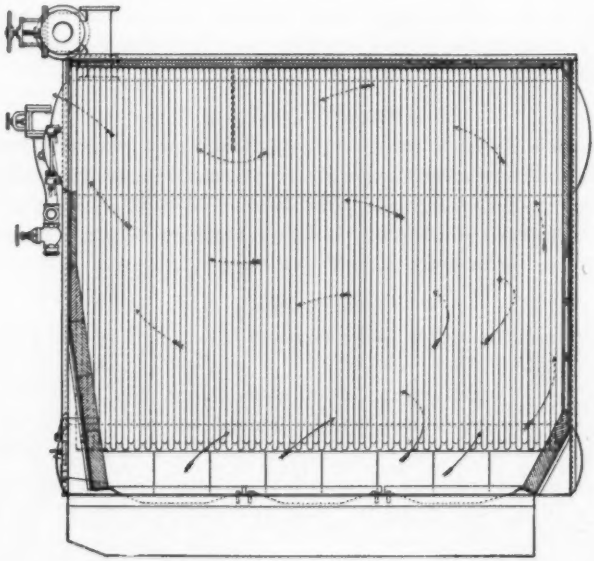
The forced draft for each fire room is supplied by one 42-inch blower, which draws the air from a ventilator on deck and also from the adjacent engine room, and delivers it, all around the periphery of the runner, into the closed fire room. The fan is driven by a horizontal compound engine, secured to the vertical bulkhead between the engine room and the adjacent fire room. The engine is on the engine room side of the bulkhead, and the blower, on the fire room side. The steam cylinders are 4 and 6½ inches in diameter, the stroke being 4 inches. The H.P. and L.P. cylinders are opposite each other and the cranks are at an angle of 180°.

ELECTRIC PLANT.

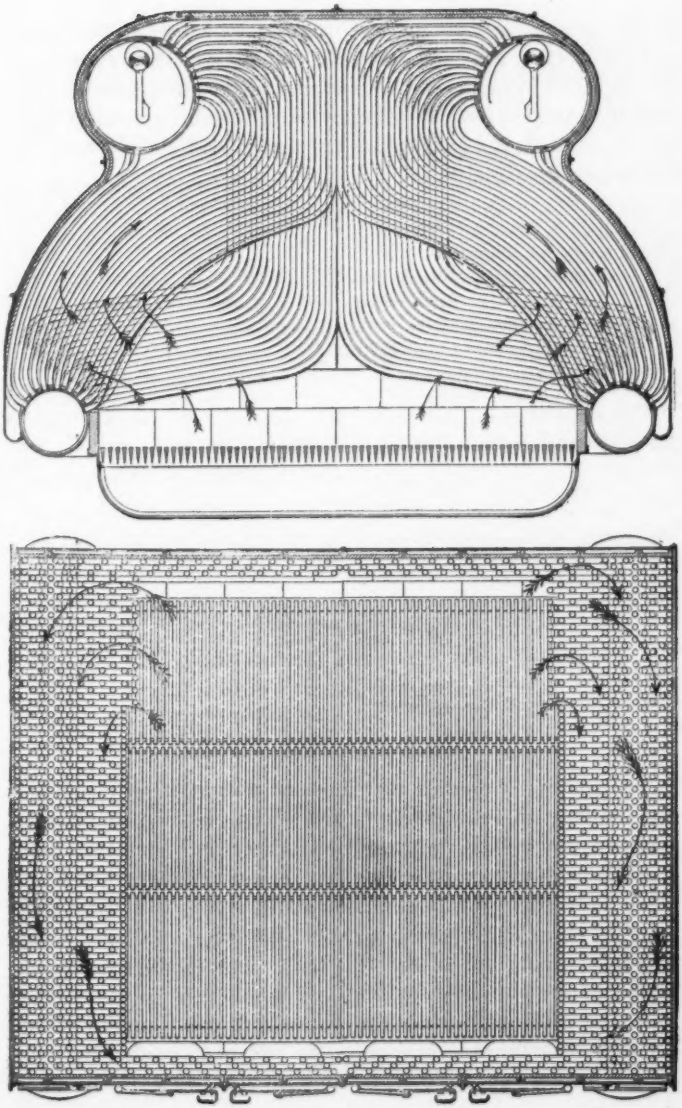
A small dynamo, having a capacity of 25 incandescent lamps, is located in the after engine room. All the wires are led through iron tubing insulated on the inside, in the place of the ordinary wood mouldings. The dynamo, which is of the quadripolar type, is driven by a single-cylinder, vertical, inverted engine connected directly to the armature shaft. The diameter of the cylinder is 3½, and the stroke, 3 inches. The engine and dynamo were built by the General Electric Company.

BOILERS.

The plans for the machinery, on which the contract was let, included two water tube boilers designed by the Bureau of Steam Engineering. During the work of construction, the contractors desired to substitute the Mosher boiler, and the request was approved. This boiler is shown in the cuts.



There are two water tube boilers of the Mosher type. The steam and water drums are made of steel, and the tubes, of lap-welded charcoal iron. Each boiler has two water drums and two steam drums; the two sides or parts of the boiler have no communication except through the main steam pipe, so that each side is independent, although the furnace is common to the two. To each steam drum are fitted the usual water gauge glasses and try cocks, while to an opening in each steam drum is attached the main stop valve, the chamber of which carries the nozzles for attaching the safety valve. A particular feature



of the arrangement of the stop and safety valves is the fitting by which they are worked from the deck. This consists of a knuckle joint frame work, so connected to the stop valve stem and the safety valve lever that, by simply turning a single hand wheel on deck, the stop valves are closed and the safety valves opened at the same time.

DATA FOR ONE BOILER.

Drums, length, feet and inches	10- 4
diameter, internal, steam, inches	22
water, inches	14
steam, thickness of plates, inch	$\frac{9}{32}$ and $\frac{1}{2}$
water, thickness of plates, inch	$\frac{7}{16}$ and $\frac{1}{2}$
Furnace, number	1
width, inches	76
length of grate, feet and inches	7- 6
Tubes, number of ordinary, No. 12 L.S.G., (.104 inch thick)	1,090
heavy, next to fire, No. 10 L.S.G., (.128 inch thick)	212
outside diameter of all, inches	$1\frac{1}{8}$
heating surface, square feet	2,606
Plate heating surface, square feet	24
Total heating surface, square feet	2,630
Grate surface square feet	47.5

TOTALS FOR TWO BOILERS.

Heating surface, square feet	5,260
Grate surface, square feet	95
Ratio of grate surface to heating surface	1 : 55.39

WEIGHTS OF MACHINERY.

The contract provided that the total weight of all machinery and boilers, including auxiliaries, steam heating appliances, water in the boilers, condensers and pipes, and such stores and spare parts as were supplied by the builders and carried on board when fully equipped, but not including stores and spare parts supplied by the Government, steam steering gear and steam windlass, should not exceed 59.2 tons. In case the total weight of machinery exceeded 59.2 tons, deductions were to be made from the price of the vessel at the rate of two hundred dollars per ton. Should the total weight of 59.2 be exceeded by 5 per cent., a further deduction of one thousand dollars was to be made-

As actually built, the finished weights of all machinery, including auxiliaries, water, tools and stores furnished by the builders was 113,848 pounds, or 50.82 tons. Using the designed I.H.P. of 2,000, this would give 56.92 pounds per I.H.P.

The weights in detail are as follows:

	Pounds.
Main engine cylinders,	10,336
Shafting,	12,690
Main engine framing and bearings,	6,649
Reciprocating parts, main engine,	2,524
Main engine valve gear,	1,875
Main condensers,	3,751
Main air and circulating pumps,	1,273
Propellers,	1,197
Main boilers,	28,056
Boiler fittings,	8,355
Smoke pipes and uptakes,	1,409
Steam and exhaust pipes and valves,	4,668
Suction and discharge pipes and valves,	3,408
Lagging and clothing (including boiler casing),	3,813
Flooring, gratings, etc.,	2,372
Auxiliaries,	3,612
Fittings and gear,	2,486
Water,	11,007
Stores, tools, spare parts, etc.,	1,184
Miscellaneous machinery,	3,183
Total,	113,848

THE TRIAL.

The official trial was run on Friday, June 25, and consisted of two runs over the official course of 24½ nautical miles in Chesapeake Bay, off the mouth of the Patuxent River.

The boat steamed from the works in Baltimore to Annapolis on Thursday afternoon, and lay over night at the Naval Academy wharf. The start was made the following morning; fires in the after boiler were cleaned and fires started in the forward boiler, after steaming down the bay to a point several miles above the

beginning of the course. The start over the line was made at 10 hours 52 minutes 21 seconds, A. M., and the last buoy was passed at 11 hours 52 minutes 8.5 seconds, A. M., the elapsed time being 59 minutes 47½ seconds. On the return run, the line was crossed at 12 hours 1 minute 15 seconds, P. M., and at the finish, at 1 hour 1 minute 17½ seconds, P. M., the elapsed time being 1 hour 0 minutes 2½ seconds. The total time on the course was 1 hour 59 minutes 50 seconds, giving an average speed of 24.534 knots. The tidal corrections applied to the course, made the latter 49 nautical miles long. The weather was fine with light airs, and the sea smooth.

No indicator cards were taken during the trial; only the revolutions of the main engines, the steam, 1st and 2d receiver pressures, vacuum, and the air pressure were observed and recorded.

These observations were made at the start and finish of each run, and at fifteen minute intervals while on the course, and are shown in tabular form below.

	Revolutions per minute.		Steam pressure, pounds per square inch.						Vacuum ins. mercury.		Air Pressure ins. water.	
			At Engine by gauge.		1st Receiver absolute.		2d Receiver absolute.					
	S.	P.	S.	P.	S.	P.	S.	P.	S.	P.	F.	A.
Run South.	.....	.....	240	242	75	82	15	12	23	22	3½	3¼
	410.67	401.33	242	240	75	82	13	16	24	20½	3½	3¼
	398.67	383.33	240	235	73	77	13	10	23	22	3½	3¼
	393.33	384.0	235	240	73	77	13	9	22	22½	3½	3
	392.79	395.16	240	240	80	81	18	11	22	22¼	3½	2½
Run North.	.....	.....	240	235	75	77	11	10	22	22½	3¼	3½
	392	383.33	230	245	70	85	11	15	22	21½	4	4
	396.67	389.33	240	245	73	87	14	16	22	21	4	4
	402.0	407.33	241	250	75	87	15	17	23	21	4¼	4½
	398.88	402.54	240	245	75	90	13	10	23	21	4½	4
Averages.	398.14	393.30	238.8	241.7	74.4	82.5	13.6	12.6	22.6	21.6	3.75	3.42

Total number of revolutions, starboard	47,710
port	47,130
mean	47,420
Revolutions per minute, mean of both engines	395.72
Speed, knots	24.534
Slip of starboard screw, per cent	20.29
port screw, per cent	19.31
both screws, average, per cent	19.80

USE OF WATER TUBE BOILERS IN THE MERCANTILE MARINE.

By Albert Edward Seaton, M. Inst. C. E.

[Read at the Institution of Civil Engineers, Engineering Conference.]

The resurrection and revival of the water tube boiler and its successful employment for naval purposes, has naturally caused the question to be asked on all sides, "Cannot such boilers be used with advantage in the mercantile marine?" and, as may be supposed, the replies of engineers differ very largely on the subject, varying between the extreme opinions that there is nothing to hinder their immediate adoption, and that such boilers are not, and never can be, fit for mercantile steamships. The controversy, both in political and professional circles, has practically revolved round one particular form of water tube boiler, so that the general merits of the case have been confused, and in many instances entirely lost sight of.

The water tube boiler first appeared in America in the very early days of this century, long before Queen Victoria ascended the British throne. The object of Colonel Taylor, in 1807, was to substitute for the heavy, roomy and somewhat inefficient Cornish boiler a generator more suitable to the exigencies of shipboard, and that after experience with the paddle steamer *Claremont* on the Hudson. It will thus be seen that at the outset the distinguishing features of a water tube boiler, viz: light weight and small space occupied, operated to cause it to be proposed in the mercantile marine of America. Many efforts have since been made in America to employ a water tube boiler of some kind or other in mercantile ships, so that to-day the engineers of the United States are in a much more receptive mood for the adoption of the water tube boiler than are the engineers of this country, where hitherto the attempts to use that

form of boiler at sea have been few and far between, and mostly attended with ill-success. The possibilities of the water tube system have not, however, either in this country or in any other, been exhausted; and although there are at the present time many types in successful use, none altogether fulfill the necessary conditions for the best form of water tube boiler.

Considering the ideal water tube boiler to consist altogether of cylindrical components, with either spherical ends or ends of such a form as to require no staying, and subject only to internal pressure, it needs little demonstration to show that such a boiler must be lighter, stronger and more capable of withstanding rough usage than a boiler which is a combination of cylindrical components (a large portion of which is subject to external pressure), rectangular boxes, flat ends, &c.; and therefore it will be assumed that it is in itself lighter than the Scotch boiler, pressure for pressure, and especially so for high pressures; that it contains less weight of water than its rival; that it can be designed to occupy as little or even less space than the Scotch boiler; and that steam can be got up in it in half an hour as against four to six hours with the Scotch boiler. All these assumptions are, however, borne out by recent practice.

In H.M. Navy, experiments with both the Belleville* and Thornycroft boilers have shown that the type can be worked as economically as to fuel as the Scotch boiler, and that the amount of coal required to get up steam is considerably less. There is, indeed, no *prima facie* reason why a water tube boiler, properly designed and properly worked, should not be capable of evaporating as much water from a pound of fuel as the ordinary boiler can.

The enduring powers of the water tube boiler have not yet been demonstrated, and as that is a question of cost, it necessarily has a very important bearing in determining their use in commercial steamships. But here again there are no *prima facie* reasons why a water tube boiler should not last as long as any

* 10.3 pounds of water per pound of coal (from and at 212 degrees) has been evaporated from the boilers of H.M.S. *Furious* when burning over 30 pounds of coal per square foot of grate in the trial on May 10.

other boiler; indeed, there are many reasons why it should last longer, not the least of which is the fact that it is not subject to distress of itself as a whole, or of any of its more important parts, on rapidly raising steam, or on rapidly cooling down, whereas a Scotch boiler is very materially affected by these circumstances, and the length of its life is probably in the inverse ratio to the number of times steam is raised in it. It must, however, be understood that this statement does not imply that any of the existing boilers comply with the ideal conditions, and consequently their lasting powers may possibly be not so great as that of the Scotch boiler; but the evidence of the boilers that have been fitted into ships of the mercantile marine points in the direction of equal or greater longevity for the water tube boiler.

The prime cost of the Belleville boiler is undoubtedly very much greater than that of the best cylindrical boilers, and it is probable that every kind of water tube boiler in which so much screwing and so much accuracy of fitting is involved, and for which so many special fittings are required, will always exceed the cost of the old type of boiler; but the Babcock & Wilcox boiler, and boilers of the type in which the tubes are simply expanded in place, and for which no special appliances are necessary either for circulation or for fuel burning, cost little or no more than the ordinary boiler. Experience with both the Belleville and the Babcock boiler has shown that defects and mishaps may be remedied at sea by the vessel's own staff, and that mishaps of a more serious nature can, at comparatively slight expense, and in a short time, be effected in port. On the other hand, the mishaps to the tank boiler, especially when it is getting old, are much more serious, can very seldom be repaired at sea, and when done in port necessitate a considerable expenditure of time as well as money.

With existing designs of water tube boiler, a little more care in stoking is necessary, especially if the best results from the fuel are required; but there is nothing so serious as to prevent the ordinary every-day marine fireman from being educated in a few hours to manage the fires of a water tube boiler as well as

he manages those of the Scotch boiler. From the conditions of employment in the mercantile marine this is likely for some time to be a difficulty; still, it is not an insuperable one, and, if ships' engineers will take the proper precautions, need not be one of long duration in any ship.

The ideal boiler referred to, or, perhaps, preferably, the boiler of the future, because it is not likely that any boiler will ever quite fulfill every requirement of an ideal boiler, must have a rapid, uniform and definite circulation, the upcast tubes should be very considerably inclined from the horizontal (and the nearer they are to the vertical position the better); they may be large or small, according to fancy or circumstances, they should be capable of easy examination, and therefore must be straight or nearly so, and their arrangement should be such that any one of them may be easily drawn and replaced; the downcast pipes, or those from the steam drum to the water pockets, should be as direct as possible and of considerable size, and at or near their bottoms there should be a receptacle with no circulation, in other words, a dead end, so that solid matter can, by gravity, be separated from the liquid; the fire place and its surroundings should be of such a size and nature as to allow of the proper combustion of the fuel and its effluent gases, while the general structure of the boiler should be such as to enable it to bear sudden expansion and contraction with impunity, and the whole of the surface exposed to flame and hot gases should be accessible for cleaning. If these conditions are fulfilled, there is no absolute necessity for using pure fresh water, inasmuch as the rapidity of flow will prevent deposition on the upcast pipes by the mechanical scour of the water; the dead ends permit of the deposit at a safe place, and if there is any deposit on the downcast pipes, they (being of considerable size and easy of access) can be cleaned when opportunity serves, and, if necessary, would go for a considerable period without cleaning. The absence of these conditions in the boilers of the *Propontis* and other ships which have not been successes, has no doubt conduced to their failure, and although to-day the means of obtaining fresh water by evaporators, &c., permits of the use of pure water in boilers,

and has, to a large extent, been the means of the admission of these boilers on shipboard, it is really no more a necessity with the type when properly designed than with the Scotch boiler.

The shipping of the mercantile marine may be roughly divided into (1) passenger steamers pure and simple; (2) cargo steamers carrying passengers; and (3) cargo steamers pure and simple. The passenger steamer must necessarily be a fast one, and is usually of 14 to 22 knots speed. Its speed is dependent on its form and the power its machinery can develop. Without the fine form the largest power is unavailing for speed, and without the necessary power the fine form is useless. Fineness of form means minimum of displacement, and consequent minimum weight of hull and machinery. Great power means great weight, therefore in this class of ship everything is resolved into a question of weight. The hull of the vessel has to be designed and constructed in accordance with the rules and regulations of registries and the Board of Trade, which circumscribe the designer. The engineer in designing the machinery is similarly fettered; but he can, by causing a small engine to work at a large number of revolutions, and by skillful design, considerably reduced the weight per indicated horse power. The great item of weight, however, is the boiler and the water contained in it. Consequently, by changing from the heavy Scotch boiler, with its mass of water, to the lighter water tube boiler, with its small quantity of water, much more horse power can be developed in the ship, or her lines may be fined, or there may be modifications in both directions with perhaps the best results. Large numbers of passenger steamers are on short service, making daily or nightly runs of a few hours at a time, steam being raised on each occasion, and lowered when done with. The water tube boiler accommodates itself admirably to this; and not only so, but seeing that steam can be raised in half an hour, the boiler room staff of such a boat can have ample rest between the runs, besides requiring only a small consumption of fuel to raise steam, so that even if the boiler when running is not so economical as the Scotch boiler, the total result of a run of a few hours' duration is a consumption of no more coal. It is also necessary in

passenger steamers that the running should be uniform. The water tube boiler, with its very high pressure and reducing valve, permits of this, as the variation of pressure in the engine room is exceedingly slight.

With the second class of steamers, namely, the cargo and passenger boat combined, speed is desirable, but it must not be on extravagant conditions; it is usually from 12 to 15 knots; therefore any saving in weight by the adoption of a water tube boiler would not be taken advantage of to increase the speed very largely by increasing the power, but it might, and probably would, lead to an increase in speed by the fining of the ends of the ship without loss of cargo carrying power. If, however, the owners were quite content with the speed, they could effect a very considerable gain in the increased cargo carrying capacity obtained by the saving in weight of machinery; in some trades and in some ships the difference would often mean a useful margin of profit instead of a loss. In certain vessels of this class a saving in weight of boiler would permit of the carrying of a larger quantity of fuel, which might be bought at a cheap port and enable the ship to return to a cheap port instead of being obliged to purchase it at a dear one, as is often the case now; and this without disturbing the question of cargo carrying, so frequently a nice point with ships of this class. In the cargo and passenger steamer in short trades, the same advantages in the raising and lowering of steam would be appreciated as in the passenger ship.

In the cargo boat pure and simple, the water tube boiler does not make such a good bid for acceptance as in the other two classes; but it has still something to offer, especially to those of moderate and small size, namely, the advantages stated above for the cargo passenger steamer.

There are not lacking signs that the final adoption of the water tube boiler in the mercantile marine will be preceded by the use of a mongrel form or combination of a water tube and a tank boiler, and in some respects such a boiler is more tempting to the mercantile engineer than the pure article. Such boilers would, of necessity, contain more water than the water tube

boiler, pure and simple, and consequently would not evaporate dry in so quick a time in case of the feed failing temporarily—a fear often expressed by practical sea-going men. The tank portion of the boiler with the internal tubes is also supposed to be a cure for flaming at the funnels, as well as for economizing fuel; but, when it comes, the boiler of the future will be found not to require such an appendage for either purpose.

The water tube is also likely to be tried tentatively in the immediate future by fitting certain mercantile ships with an installation of half tank boilers and half water tube boilers, in order that the advantages of both systems may be enjoyed, viz., the rapid getting up of steam to leave port, with the bringing into action of the tank boilers later on, and the saving of a portion of the weight that is possible. Unfortunately such an

TABLE I.

	S.S. *Dido*, No. 403.	S.S. *Othello*, No. 408.	S.S. *Zero*, No. 407.	S.S. *Cameo*, No. A 57.	S.S. *Hero*, No. 394.
Indicated horse power	2,200	2,200	1,433	1,201	1,465
Number of boilers	Three single-ended.*	Three single-ended.	Two single-ended.	2 Babcock & Wilcox.	2 Babcock & Wilcox.
Size	11 ft. 6 in. by 11 ft. 4 in.	14 ft. 3 in. by 11 ft. 6 in.	13 ft. by 11 ft.		
Working pressure	200	200	200	200	200
Total heating surface, square feet	3,971	6,414	3,814	4,400	4,400
Grate area, square feet	120	181.5	108	88	88
Weight of boilers, uptake and lagging to funnel and base, tons	100	137	76¾	38¾	40¼
Weight of hot water, tons	40½	63	33½	10¼	10¾
Weight of fire mountings and bricks, tons	9¾	10	5¼	9¼	9¼
Weight of boiler mountings, tons	4½	5	3½	3½	3½
Weight of fans, heater tubes, &c., tons	14¾	none.	none.	none.	none.
Weight of seatings, tons	7	4	2¼	4	3
Total weight of above, tons	176¼	219	119	66	67
Indicated horse power per ton	12.48	10.04	12.04	18.19	21.85

* Ellis & Eaves' system of induced draft with Serve tubes.

TABLE II.—WEIGHTS, ETC., OF BOILER INSTALLATIONS FOR

	Closed Stoke-hold.	Martin.	Ellis & Eaves.
		Induced.	Induced.
Number and description of boilers	4 double-ended cyl.	4 double-ended cyl.	4 double-ended cyl.
Size of boilers	15 ft. 2 in. by 19 ft. 6 in.	15 ft. 2 in. by 19 ft. 6 in.	14 ft. 9 in. by 20 ft.
Working pressure, boilers, pounds	200	200	200
engines, pounds	200	200	200
Total heating surface, square feet	20,000	20,000	.....
grate area, square feet	536	536	.....
Air pressure, inches of water	1 to 1½	.....	.....
Weight of boilers, uptakes, lagging, to funnel base, tons	355	359 (with fan casings).	410
hot water in boilers, tons	159	159	140
fire mountings and bricks, tons	30	30	35
steam and water mountings, tons	5	5	5
fans, air blowers and heater tubes, tons	9	9 (without casings).	45
air tight flats, locks and seatings, tons,	12¼	7	7
Total weight of above, tons	570¼	569	632
I.H.P. per ton	17·54	17·57	15·57
Weight of funnels, tons	18	17	16
stokehold floor, tons	7½	7½	7½
feed pumps, tons	5	5	5
copper pipes, tons	6½	6½	6½
spare gear, tons	5	5	5
separators and reducing valves, tons,	.....	.....	.....
ash hoisting engine, tons	1	1	1
coal carried for 64 hours × 25 per cent., tons	700	700	600
Total weight of installation, tons	1,313.25	1,311	1,283
I.H.P. per ton	7.61	7.62	7.8
square foot of grate	18.65	18.65	18.63
Total heating surface per I.H.P.	2	2	1
Pounds of coal per I.H.P. per hour	1.96	1.96	1.61
Length of boiler space over bunkers, feet	124	124	112

The above weights, &c., are based on the assumption that Welsh coal is used, and that the consumption of steam for all purposes throughout the voyage will be equivalent to 16 pounds per I.H.P. per hour.

PASSENGER STEAMER, 10,000 INDICATED HORSE POWER.

Howden.	Belleville.		Babcock and Wilcox.		Seaton.	Thorny-croft.
Forced.	Forced.	Natural.	Forced.	Natural.		
4 double-ended cyl. 13 ft. 9 in. by 19 ft. 6 in.	Twelve 11-element. 4-in. element tubes, 2¾-in. economizer.	Eighteen 11-element. 4-in. element tubes, 2¾-in. economizer.	10	12	8 double-ended.	8 single-ended.
200	260	260	200	200	250	210
200	200	200	200	200	200	200
15,460	21,000	31,500	27,000	32,400	26,000	28,000
436	633	950	615	738	536	480
1 to 1½	¾	.....	1 to 1½	.....	1½ to 2	1 to 1½
267	150½	206¼	200	246	155	105
132	22	32	66	79	60¼	16¾
31	75	112	70	85	32½	25¼
5	6	8	6	7	6	6
7¼	23½	43¾	9	4	9	4
13¾	13½	20¼	20½	18	12	11¾
455¾	290½	422¼	371½	439	274¾	168
21.94	34.4	23.69	26.94	22.82	36 0	59.5
20	17	25½	20	21	18	15¾
7½	7½	11½	6½	5½	6½	5¾
5	5	5	5	5	5	5
6½	9	10	6½	6½	6½	6½
5	10	15	5	5	5	5
.....	7	10	.....	.....	1¾	1¾
1	1	1½	1	1	1	1
475	625	750	720	720	700	725
975.75	982	1,259.75	1,135	1,203	1,018.50	934.50
10.24	10.18	7.99	8.81	8.31	9.82	10.73
22.91	15.8	10.52	16.26	13.5	18.65	20.62
1.54	2.1	3.15	2.7	3.24	2.6	2
1.33*	2.1	1.75	2.01	2.01	1.96	2.06
97	124.75	145	99.25	105	112	104

* This estimate of the coal consumption per indicated horse power has been supplied by Messrs. James Howden and Co. I am not prepared to say that it is verified by personal observation made from sea-going practice. The coal consumption given, viz., 1.33 pounds per indicated horse power per hour, when taken in conjunction with the water consumption per indicated horse power per hour, would mean that the evaporation of water per 1 pound of coal would be 12.03 pounds from and at 212 degrees.

arrangement also possesses the disadvantages of both systems. Judging by the animosity of certain inventors, one would suppose that the water tube system was incapable of enjoying the benefits of their inventions; but this is not so; in fact, it was not certain that the definite supply of heated air is not of greater advantage to the water tube boiler than to the Scotch type.

It may be asked, "Is there any reason for discarding the present form of boiler, which has done good service so long in the mercantile marine?" The same reasons which have brought about the change in warships apply equally well to a large number of merchant ships. The desire for higher pressures of steam is expressed unmistakably by every class of shipowner, as much from him who directs the great lines of ocean express steamers as from him who owns the humble trawler; and the steam tramp managers vie with one another who shall have the highest pressed boiler. Speeds which a few years ago were deemed impossible with the largest ships are now required with comparatively small ones, and are obtained by raising the working pressure and decreasing the boiler and adopting forced draft. A pressure of 200 pounds per square inch is not enough to satisfy the demands, and even now 250 pounds is spoken of as desirable. A Scotch boiler for this pressure, even of moderate size—say 14 feet in diameter, and having three furnaces 40 inches in diameter—will require shell plating $1\frac{25}{32}$ inches thick, furnaces $\frac{3}{4}$ inch thick, and $1\frac{1}{2}$ inches diameter screwed stays $7\frac{1}{2}$ inches pitch, with combustion chamber plates $\frac{5}{8}$ inch thick. The shell must have treble riveted seams throughout and double butt straps at the longitudinal joints; the rivets will be $1\frac{7}{8}$ inches in diameter, and only hydraulic machinery of massive type can close them. The furnaces may at any time collapse should a little grease by accident get into the boiler. The combustion chamber is liable to serious bulging from the same cause; and the stays fracture if careless firemen get steam too rapidly a few times. The life of the ordinary Scotch boiler, with a working pressure not exceeding 100 pounds per square inch, and of which every care has been taken, is from 10 to 20 years, depending on the service; that of similar boilers for 200 pounds to 250 pounds pressure is not likely to

be nearly so long. That such a boiler is liable to the accidents above named is amply proved by present every-day experience. Most of the water tube boilers as now made, and those likely to be made in the future, will have no part thicker than $\frac{1}{4}$ inch directly exposed to heat, and although from the same causes accidents may ensue, they will be of a comparatively trivial nature, easily remedied, and not likely to cause serious damage to the surroundings or to life and limb.

There appear, therefore, good *prima facie* reasons for expecting the adoption of the water tube boiler in the mercantile marine in the immediate future, and that satisfactory results will be obtained by its use; but caution is necessary both in the choice of design of boiler and in the arrangements of the same, and care should be exercised in seeing that such boilers are properly constructed and properly fitted in the ship, as well as properly looked after when there, especially as the economic working of these boilers depends so much on care and attention to details.

Table I, prepared by a member of the author's staff, Mr. A. H. Tyacke, shows at a glance the fullest particulars of the different kinds of boilers, as determined by their makers or advocates, for engines of 10,000 indicated horse power.

Table II is a statement of the weights, &c., of some water tube boilers fitted by Earle's Shipbuilding and Engineering Company into ships during the past two years, and those of Scotch boilers fitted in similar ships during that time.

ON THE FORMATION OF CAVITIES IN WATER BY SCREW PROPELLERS AT HIGH SPEEDS.

By Sydney W. Barnaby, M. I. N. A.

[Read at the International Congress of Naval Architects and Marine Engineers, July, 1897.]

In a paper* upon torpedo boat destroyers, read before the Institution of Civil Engineers in 1895 by Mr. Thornycroft and myself, we gave some particulars of the screw trials of the *Daring*, and described briefly the reasons which led us to conclude that a new phenomenon was manifesting itself. This phenomenon seemingly pointed to the probability that the speed of vessels was approaching a stage at which propulsion by screws would become less efficient, and we said that it appeared inevitable that reduced efficiency must be submitted to as the speed of vessels increased.

If a cavity be formed in any manner in the interior of a mass of water it will tend to become filled with water vapor and with any air which might be in solution, since ebullition takes place at ordinary temperatures in a vacuum. We believed that at the speed at which the screws of the *Daring* began to give trouble such cavities were being formed, and were the source of the great waste of power and of other difficulties which were experienced.

This view met with not a little incredulity at the time, but I believe it to have been perfectly correct. The trials of the *Turbinia* and the experiments made by Mr. Charles Parsons, and described by him in this Institution in April last,† afford very strong, if not complete confirmation of our contention. Even

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*See page 711 of Volume VII of the Journal.—Edit.

†See page 374 of the May number of the Journal.—Edit.

without this confirmation, the fact that the steps were successful which we took to overcome the difficulty, when we had, as we believed, discovered the cause, afforded strong evidence of the correctness of the diagnosis. As the subject may not have been brought to the attention of many of our foreign friends, I thought a short explanation of the theory of cavitation might be of interest if made as lucidly as its nature will admit and accompanied by a statement of the experience obtained with the *Daring* upon which it is based.

Put shortly, the facts were these. With a pair of three-bladed screws 6.16 feet (1^m,88) diameter, 9 feet (2^m,75) mean pitch, and 8.92 square feet (0^{m2},83) developed surface, the *Daring* attained a speed of 24 knots with 3,700 I.H.P., the screws making 30 per cent. slip. With a pair of screws of the same diameter, and practically the same mean pitch, but with a surface of 12.9 square feet (1^{m2},2)—an addition of 45 per cent. to the surface—the same speed was obtained with 650 less horse power, and with $17\frac{3}{4}$ per cent. slip instead of 30 per cent. The number of revolutions required for 24 knots with the screws of small area sufficed to drive the vessel at 28.4 knots when the blade area was increased. The vibration was unprecedented and dangerous with the narrow blades; it was of quite a normal and unimportant character when the blades were widened.

In order to arrive at a clear understanding of what is believed to take place, it is necessary to distinguish between the two cases —firstly, that of a propeller drawing air from the surface; and secondly, that of the formation of cavities when the propeller is submerged. The effect upon the thrust of a fast-running screw when the blades break the surface of the water or when air penetrates from the surface is well known. Under such conditions the velocity at which water can flow, due to gravity at a depth h below the surface, is equal to $\sqrt{2gh}$, and amounts, for example, to only $8\frac{1}{2}$ knots at a depth of one meter.

If the velocity with which a portion of the blade situated at a depth h moves is less than $\sqrt{2gh}$, the water will keep in contact with it, even if the blade break the surface, and there will be no loss of efficiency. This is the case with the slow-moving, par-

tially, submerged screws used by Mr. Barcroft to propel barges on the Irish canals, as described by him in a paper recently read at the Institution of Mechanical Engineers; and it also probably explains the good results obtained with the partially-submerged screws of large blade area employed in some shallow draught tugs on the Continent. The speed of the float of a paddle wheel is limited by the same condition. The particulars of a large paddle steamer, having feathering wheels 20 feet 6 inches (6^{m},25) over the floats, which are 9 feet 9 inches (2^{m},98) by 3 feet 6 inches (1^{m},065), have been supplied to me. I find the slip—*i. e.*, velocity of float in relation to still water—is 11.2 feet (3^{m},41) per second. In order that the water should attain this speed, it must have a fall of $h = \frac{v^2}{2g} = \frac{11.2^2}{64.4} = 1.95$ feet (0^{m},595), so that, if the top of the float was just awash when at rest, then, assuming that at the position of the wheel there was neither a wave crest nor a wave trough due to the motion of the vessel, the water would fall away from the float when in motion for a depth of nearly 2 feet, leaving 1½ feet only immersed, as it would only be at this depth that the speed of the water due to gravity would equal that of the float.

I do not know whether designers of paddle wheels are in the habit of calculating in this way the probable immersion of the floats at full speed, but I think they might find it useful to do so.

When the screw is sufficiently submerged to exclude air from the surface, the rate at which the water can be accelerated is very much greater. This can be illustrated as follows. Water will flow from a tank through an orifice discharging into the open air at a velocity depending upon the depth of the orifice below the surface of the water in the tank.

It will flow through the same orifice into the exhausted receiver of an air pump at a much higher velocity, depending upon the degree of exhaustion in the receiver. The velocity in the latter case will be that due to the head of water plus the difference between the pressure of the atmosphere and that in the exhausted receiver. Similarly, the velocity with which water can be made to flow towards a submerged screw is due to the

head of water over the screw plus the atmospheric pressure, and there is consequently a definite limit to the speed to which it can attain.

It was not easy to calculate theoretically at what point the breakdown would occur with a given propeller, but a way of attacking the problem suggested by Mr. Thornycroft proved to greatly simplify it, and to render its solution possible. His idea was that there must be a definite thrust per square inch of projected screw surface at which cavitation commenced.

A screw propels by putting water in motion sternwards. It effects its object partly by pushing the water with the after face of the blades, and partly by pulling it with the forward face. I will ask you to imagine that we have replaced the screw of a ship by a disc of rather less diameter than the screw, and that, instead of revolving the screw shaft, we push the shaft and disc sternwards at such a speed that the momentum of the water moved by the disc is equal to the sternward momentum of the water put in motion by the screw. The propelling effect would be the same as that of the screw,* and so far as the action between the forward face of the screw blades and the contiguous water is concerned, which is what I wish to illustrate, the action of the disc affords a sufficiently close analogy. As the disc moves sternwards, it puts water in motion not only astern of it, but also ahead of it. There being no air between the water and the front face of the disc, a pull can be exerted upon the water, which is forced to follow the disc in the same manner that water is forced to follow the plunger of a pump.

But the pull which can be thus exerted by the disc is limited. At a little depth beneath the surface of the water, if the tension exceeds 15 pounds per square inch (one atmosphere), the surfaces of the disc and adjacent water are torn asunder, and a cavity is formed between them.

As but a little more than half of the total acceleration imparted to the water by a screw is estimated to be produced by the suc-

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* This would not be true if the movement of the disc were continued far beyond the stern post, but is nearly so if the movement is confined to the length of the screw.

tion of the forward surface, it might be supposed that a total thrust approaching to 30 pounds per square inch (two atmospheres) might be obtained, but it appears that rupture occurs at parts of the screw surface long before the mean thrust per square inch of the whole surface reaches this amount. This is probably accounted for by the fact that the thrust of portions of the screw blade near the circumference is much greater than at portions near the boss.

By plotting the results of a progressive trial carried beyond the speed at which cavitation commenced, we were able to note the point at which the first indications of failure appeared. It is not marked by a sudden change, but by a flexure in the curve of slip, which commences to rise rapidly when the critical speed is reached.

The total thrust of the screw at this speed divided by its projected blade area gave a thrust of 11¼ pounds per square inch (0.75 atmosphere), which is, therefore, about the maximum thrust which can be obtained from a screw working efficiently at a depth below the surface of 11 inches (0^{m},28), which was the immersion of the tips of the blades in the *Daring*.* For every additional foot of immersion, the total thrust per square inch may be increased by ⅜ of a pound.

By means of the very ingenious expedient of trying a model screw in water heated nearly to boiling point, Mr. Parsons has been able to reproduce and examine the phenomenon of cavitation, and has corroborated our figure of 11¼ pounds as the thrust at which it commences.

The difficulty of reproducing analogous conditions with a model lay in the high speed of revolution necessary; but by heating the water, and thus increasing the vapor pressure, lower speeds became possible. Since the tension of the water vapor at boiling point is equal to atmospheric pressure, a screw would cavitate in boiling water at the same speed as it would do if air were admitted to it. In other words, steam would be given off

* The figure should vary slightly with the pitch ratio, being less if the latter is high, since the ratio which the suction thrust bears to the whole thrust varies with pitch ratio, but the variation is so small as to be negligible.

as soon as pressure was reduced. An analogous effect could be obtained by expanding by heat, the residue of air in the exhausted receiver before referred to. Then the reduced difference of pressure between the air within and without the receiver would cause the water to flow into the latter from the tank more slowly, and, if the temperature of the air were raised sufficiently to cause a pressure inside equal to that of the atmosphere, the rate of flow would be that due to the head of water only. The same result would be secured by using a closed tank and exhausting the air in it so that the water would flow from one vacuous region to another, and, I believe, Mr. Parsons has suggested that further experiments might be made in cold water, the surface being relieved from the pressure of the atmosphere.

That cavitation will be the cause of trouble in the future is, I think, certain. Already it is becoming difficult to obtain the requisite area in screws of destroyers without either resorting to an abnormal width of blade, or to a larger diameter and pitch ratio than would otherwise have been preferable. The one expedient gives undue surface friction, and the other necessitates a reduction in the rate of revolution, and therefore a heavier engine. The fact that the designer of the *Turbinia* has been forced, doubtless against his will, to employ nine screws in order to avoid cavitation, is an evidence of its influence, and a justification of the note of warning we raised in our paper of 1895 after the trials of the *Daring*.

THE U. S. TORPEDO BOAT *RODGERS*.

By Chief Engineer W. M. Parks, U. S. Navy.

This twin screw torpedo boat, built by the Columbian Iron Works & Dry Dock Co., Baltimore, Md., is a sister boat of the *Foote*, fully described in a previous paper in this number of the Journal.

On August 23, a series of progressive trials was made with this boat. The following description and results of these trials may be of interest.

Fourteen runs were made over a measured mile of 6,080.2 feet, laid off by the U. S. Coast Survey in Chesapeake Bay. The course is not protected from winds or tidal currents. The depth of water is about 60 feet. Sets of two runs in opposite directions were made over the mile, with boiler pressures varying as nearly as possible by differences of 25 pounds, the throttle valves being open wide in all runs. The first two runs were made with a pressure of 250 pounds per square inch, and decreased thereafter. Nothing was touched about the engines from start to finish of the runs; the pressure in boilers was regulated by the blowers.

The boat's bottom was clean and well painted. During the trials the sea was smooth at first, increasing to a rough sea towards the finish. The wind, with the tide, varied from a light to a strong breeze.

The draught of the boat, noted at the beginning of the series of runs, was 4 feet 7 inches forward and 5.5 feet aft, or a mean of 5 feet $\frac{1}{2}$ inch. The displacement corresponding to this draught is 145.6 tons, and the area of the immersed midship section, 59 square feet. The water was too rough at the end of the trials to take the draught then.

The propellers were carefully measured for pitch and area with the following results. Pitch, uniform, 7 feet 10 inches; helicoidal area of one propeller, 10.1 square feet. This area is slightly larger than that for the propellers of the *Foote*. The diameter of the propellers is 5 feet 2 inches.

Indicator cards were taken from both engines while on the mile. The steam pressures were read from gauges in the engine rooms, and the revolutions of the engines were noted by a Weaver recording instrument. Owing to a misunderstanding, the signal to the observers at this indicator, on run 10, was not given until the boat had passed the buoy. The time on the mile for that run has, therefore, been assumed, and is approximately correct, but the number of revolutions per minute is correct.

The results of the progressive trials are given in the table. The even-numbered runs were made with, and the odd-numbered ones against the tide.

On September 11, the *Rodgers* started on the official two hours' trial over the course of 24.5 miles run by the *Foote*. One run over the course had been made, and the second was more than half finished, when the port engine suddenly broke down and a violent rush of steam came out of the engine room hatches. Fortunately, the accident did not result in the death of anyone, but the engineer member of the Trial Board, who was in the port engine room at the time, was badly burned about the arms and face; some of the contractors' men were slightly scalded. The trial crew, under the direction of Chief Engineer Geo. F. Coleman, acted with great coolness and decision. The disabled engine was shut off and the boat returned to Baltimore with the starboard engine.

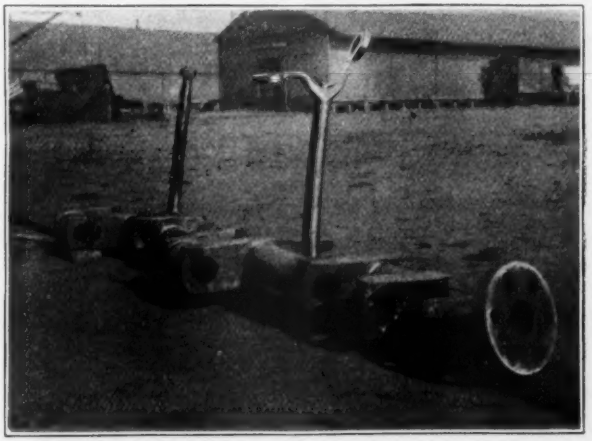
From the statement of those on board, it appears that, at the time of the accident, the after fire room was open, as the blower in that room had been disabled. On account of this open fire room, the steam pressure had dropped to between 180 and 190

PROGRESSIVE TRIALS OF TORPEDO BOAT *RODGERS*, AUGUST 23, 1897.

Number of run.	Steam pressure.	Time on measured mile.	Revolutions per minute.			I.H.P., main engines.			Speed, knots.	Slip, $^0/_0$.	
			S.	P.	Mean.	S.	P.	Total.		Mean.	Mean of 2 runs.
		min. sec.									
1	250	2–33	396.40	390.78	393.59	1,157.42	1,119.64	2,277.06	23.529	22.64	21.47
2	250	2–24.5	408.69	400.31	404.50	1,099.16	1,312.77	2,411.93	24.913	20.31	
3	222	2–30	400.40	395.50	397.95	1,172.84	1,143.94	2,316.78	24.000	21.99	20.94
4	220	2–27	398.37	392.86	395.61	1,161.33	1,133.53	2,294.86	24.489	19.90	
5	200	2–41	376.96	368.01	372.48	1,024.73	1,015.98	2,040.71	22.360	22.32	21.47
6	200	2–35.5	381.51	373.31	377.41	1,021.37	1,044.67	2,066.04	23.151	20.62	
7	177	2–51.5	355.32	343.98	349.65	868.90	830.40	1,699.30	20.991	22.31	21.55
8	176	2–49	353.43	342.60	348.01	848.56	819.79	1,668.35	21.301	20.79	
9	151	3–01	331.16	324.86	328.01	707.84	718.83	1,426.67	19.889	21.54	21.23
10	152	2–59	333.12	325.37	329.24	702.71	697.82	1,400.53	20.111	20.93	
11	125	3–13	304.43	302.18	303.30	545.47	563.23	1,108.70	18.658	20.43	20.21
12	124	3–12	304.53	301.87	303.30	533.59	539.73	1,073.32	18.750	19.99	
13	98	3–29	275.45	270.93	273.19	385.94	389.00	774.94	17.224	18.42	18.38
14	100	3–22	285.15	279.65	282.40	399.90	415.65	815.55	17.821	18.34	

pounds per square inch. The number of revolutions for this pressure was about 385, while previous to the accident as high as 410 revolutions per minute had been counted.

As the *Rodgers* had not yet been accepted by the government, no official inquiry into the accident or its probable cause could be made, but, on return to the yard of the builders, an examination of the port engine showed that this engine was completely ruined. (It may be noted here that the port engine is in the after engine compartment, and that the high pressure cylinder is forward.) Every moving piece was more or less distorted. The crank shaft was broken in three places. The after web of the high pressure



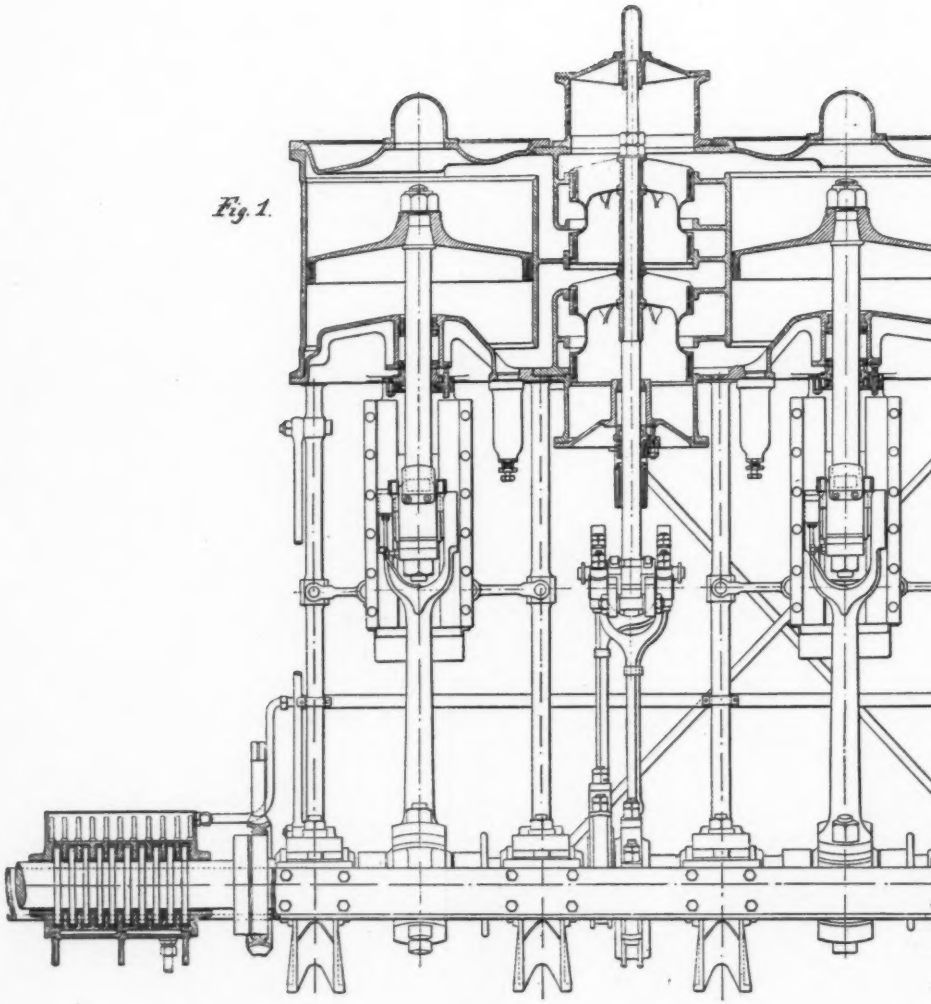
crank was broken across just below the eye for the crank pin. Another break was at the forward end of the journal between the intermediate and first low pressure cranks, the break being a little abaft of the after web of the intermediate pressure crank. The other break was also in a journal, the after journal of the second lower pressure crank. The break was right at the after face of the after crank web.

These breaks are shown in the cut, which shows the port crank shaft, with the second low pressure crank to the right, the second low pressure connecting rod and one piston rod.

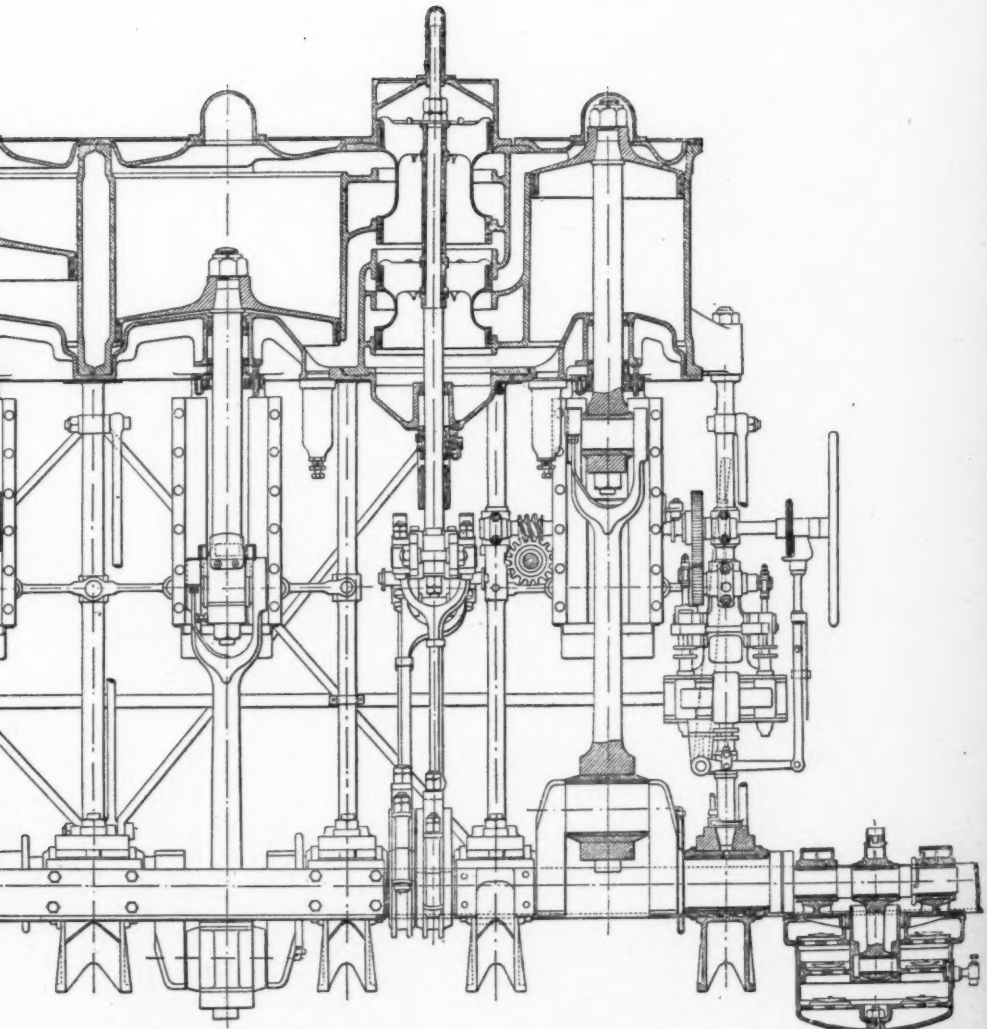
Besides the breaks in the shaft, a large part of the wall of the high pressure cylinder on the after side, and the tops of the intermediate and second low pressure cylinders were knocked out. The receiver pipe to the first receiver was broken, two main bearings were twisted and three engine columns bent. All the journals of the broken crank shaft were found to be in excellent condition, but the breaks showed a coarse-grained material with little fiber.

From all accounts and appearances, it seems to be certain that no water was carried over from the boilers.

Fig. 1.



ENGINES OF H.M.SS. "SPI



"SPITFIRE" AND "SWORDFISH."

HIGH SPEED SELF-LUBRICATING STEAM ENGINES.

[Paper read by Mr. Alfred Morcom, of Birmingham, before the Institution of Mechanical Engineers.]

The subject of high speed engines is one of such real importance and interest, that it may be useful and appropriate on the occasion of the present meeting to give some account of the part taken in their development by the writer's firm, Messrs. G. E. Belliss & Co., of this city.

Steam Cutters and Pinnaces.—In 1864 the firm commenced, with Mr. J. S. White, of Cowes, to supply to our own and foreign governments steam cutters and pinnaces for use with warships. These small boats, which are now such a feature in all our harbors, were at that time unknown. The first boat was a steam life cutter, built for the late Marquis of Hastings; the primitive engine used in it had a single cylinder 5¼ inches in diameter and 6 inches stroke. With all these small craft throughout, for naval and private purposes, the problem has been the same, namely, to get the greatest power that can be developed out of a given weight of machinery, with a reasonable factor of safety. As far as the engines are concerned, exceeding care with the design and the materials, and quick revolutions, have alone rendered advances possible in this direction; but the limits have necessarily been soon reached, and in recent years the chief advances have been made in the boilers, with forced draft to assist the combustion. The shallow draught of these vessels requires a small diameter of propeller; and this, together with the necessity for minimum weight of machinery, has always required the speed of revolution to be kept high. In these small boats, which are carried on board the ships of war, the machinery

varies in power from about 12 indicated horse power in the cutters to 200 indicated horse power in the vidette boats. The gradual progress made is illustrated by the fact that in the first vidette boat built a speed was obtained of 14 knots with 142 indicated horse power for a total weight of 5½ tons of machinery, including water in boilers, and in the last, a speed of 17.88 knots with 206 indicated horse power for the same weight of 5½ tons.

Torpedo Boats.—A considerable number of sets of machinery have also been built for first class torpedo boats and for torpedo boat destroyers, and last year the machinery was completed for two of the latter vessels—the *Spitfire* and *Swordfish*, built by Sir W. G. Armstrong, Whitworth & Co. The particulars of the machinery and of the trials are given in Tables I and II, and the engines are shown in the cut, Fig. 1.

TABLE I.—FULL POWER TRIAL OF H.M.S. *SPITFIRE*, AUGUST 17, 1896.

Draught of water, forward, 5 feet 2 inches, aft, 7 feet 4¾ inches.

Speed of ship, mean for three hours, 27.461 knots, mean on measured mile, 27.775 knots, maximum, 28.571 knots.

		Three hours full power.		Six runs on measured mile.	
Air pressure in stokeholds, inches of water		3.09		2.76	
Steam pressure in boilers, per square inch above atmosphere, lbs.		195		198	
		Right.	Left.	Right.	Left.
Vacuum in condensers, inches of mercury		24.3	23.6	24.5	24.0
Revolutions per minute		401.9	395.7	408.7	403.6
	mean	398.8		406.2	
Steam pressure in reservoirs, per square inch above atmosphere	high, lbs.	187	187	185	186
	intermediate, lbs.	87	90	85	87
	low, lbs.	24	25	24	24
Mean pressure in cylinders, per square inch	high, lbs.	68.0	70.2	65.3	69.3
	intermediate, lbs.	30.7	33.3	30.4	32.7
	forward low, lbs.	20.2	20.6	20.2	19.8
	aft low, lbs.	19.8	18.8	19.2	19.3
Mean indicated horse power	high, lbs.	686	697	668	700
	intermediate, lbs.	651	700	657	699
	forward low, lbs.	453	457	460	445
	aft low, lbs.	446	416	439	437
Total power of each set, I.H.P.		2,236	2,270	2,224	2,281
both sets, I.H.P.		4,506		4,505	

TABLE II.—FULL POWER TRIAL OF H.M.S. *SWORDFISH*, OCTOBER 21, 1896.

Draught of water, forward, 5 feet 2½ inches, aft, 7 feet 5 inches.
Speed of ship, mean for three hours, 27.117 knots.
Air pressure in stokeholds, 2.3 inches of water.
Steam pressure in boilers, 203 pounds per square inch above atmosphere.

		Right.	Left.
Vacuum in condensers, inches of mercury		24.1	24.4
Revolutions per minute		399.2	398.2
	mean	398.7	
Mean pressures in cylinders, per square inch	high, pounds	66.2	66.7
	intermediate, pounds	36.4	36.2
	forward low, pounds	19.3	19.5
	aft low, pounds	18.9	19.0
Mean indicated horse power	high	672	662
	intermediate	771	764
	forward low	431	428
	aft low	424	418
Total power of each set, I.H.P.		2,298	2,272
Joint power of both sets, I.H.P.		4,570	

The general features of these engines by all makers are similar. The engine bearers are separate light steel castings, supported on the angle frames running fore and aft between the bulkheads. From these bearers the cylinders are carried by forged steel columns suitably braced. All the working parts are made as light as possible, as the momentum due to the high piston speed, of 1,250 feet per minute on trial, is a considerable factor in the working of the machinery. A peculiar feature in these engines, which has considerably assisted in the excellent results obtained, is the arrangement of the cylinders, the low pressure being divided into two equal cylinders with cranks opposite, and the high and intermediate being also arranged with cranks opposite.

This permits the fitting of two links instead of four, reduces the fore and aft space considerably, leaves the ends clear for thrust and air pump, and gives well balanced pressures on the shaft bearings. This design was here adopted, because it has proved so effective and satisfactory in the two-crank compound engines, of which large numbers have been built by the writer's firm for supplying electric light and power. The absence of four sets of link motion and accompanying gear will be fully appreciated by every one who has had charge of machinery, developing

such large power in such small space, as is necessary in torpedo boat destroyers. The engines are balanced by small weights on the crank cheeks placed at suitable angles; and although the cranks form practically a right-angle arrangement, with these weights fitted the steadiness of the hull and machinery at all powers is remarkable. The boilers are Yarrow water tube, eight in number. By far the most important improvement in recent years in high speed ship machinery has been the introduction of the water tube boiler. This alone has rendered possible the great advances in speed; and there is little doubt that in the mercantile marine the same requirements for speed will lead to the more rapid adoption of this kind of boiler, perhaps more or less modified. The total weight of the boilers in each of the torpedo boat destroyers is 41¼ tons, which for 4,590 indicated horse power is about 20 pounds weight per horse power. Although there are no separators fitted on the steam pipes, there was not the least symptom of difficulty throughout the trials, and no instance of leakage of tubes or other parts. For the sake of comparison the weights of several classes of marine engines per indicated horse power are given in the following table.

TABLE III.—TOTAL WEIGHT OF MACHINERY PER I.H.P. IN VARIOUS CLASSES OF VESSELS.

	Pounds.
Ordinary merchant steamer,	450
Passenger mail boat, twin screw,	430
Battleship or cruiser, natural draft,	265
forced draft,	195
Torpedo gunboat, forced draft, locomotive boilers,	100
boat, forced draft, locomotive boilers,	75
Spitfire and *Swordfish*, forced draft, water tube boilers,	47

Lubrication.—The engine room of a torpedo boat destroyer during a full power trial is certainly not a comfortable situation. Constant attention on the part of a considerable number of men is required in order to ensure effective lubrication, and success largely depends on their ability, and on the care with which the lubricators are designed, and the pipes fitted and secured. Yet

to anyone accustomed to slower moving horizontal engines it is astonishing to see how easily well designed and well managed machinery of this kind gets through its difficult performance. In the early days of torpedo boats the writer had to take charge of the trials of large numbers of them on behalf of the Admiralty; and, coming as he did from the massive slow moving machinery in the ships of war of those days, he must confess to having experienced a feeling of sheer fright on finding himself for the first time boxed up in a compartment with a set of Thornycroft's machinery running at about 650 revolutions per minute. Although these engines were then, as now, the perfection of good design and manufacture, it seemed almost impossible to get through a two or three hours' trial with machinery whizzing round at a rate which rendered the details invisible. But as time went on, and the boats were satisfactorily completed, the writer's experience was that, although boilers, which of course in those days were not water tube, might give out, or vibrating pipes might burst, or other outside parts might break down, yet the engines themselves rarely gave trouble, or if they did, it was generally in some detail connected with the lubrication. But on the lubrication a great deal depended; and to ensure success the men employed about it had to be almost acrobats in their capabilities.

Since that time the field for high speed running has gradually widened, and the more advanced engineers have for long past been prepared to accept the fact that high speed is easily possible with safety, and have used it whenever circumstances have appeared to make it desirable. That it is desirable far more frequently than it is used is a statement which is being made frequently nowadays; and it will be useful to insist upon it here. After their thirty years' experience with high speed engines, it was natural for the writer's firm to come into the field with this kind of engine for supplying electric light and power. Some preliminary work showed clearly that open engines were not in a position, without further development, to compete with the Willans engines so largely used in central electric stations. These engines are excellent in design and manufacture; and the

single-acting cylinders and enclosed plan of lubrication render them quiet running, and easy to look after in the station. Their special claims in regard to economical performance had also to be taken into consideration. It was finally decided to combine a double-acting engine of ordinary construction with a system of forced lubrication, supplying oil under pressure to every bearing; and to enclose all the working parts, in order to prevent splash from the abundant oil supply, and in order to keep out dirt. In the first instance a small single cylinder engine was put in hand, and the expectations formed were more than realized by its performance. It was found, as had been anticipated, that the oil under pressure enabled the working parts, even when slack, to work without noise, and after some months' constant working at a load considerably higher than the ordinary full load for this size of engine the bearings had not worn perceptibly. A two-cylinder compound engine indicating 300 horse power was then completed for driving a dynamo at Messrs. Siemens' Charlton Works. After this engine had been at work continuously for four years, doing the full load required for the supply of electric power, it was opened out, and the working parts, which had not been adjusted during this period, were found practically unworn. These and other experiences gained during the same period proved that the plan of forced lubrication served most satisfactorily all the purposes of quiet and efficient running at high speed; and during the last year or two many hundreds of these engines have been turned out, from the smallest size up to 500 horse power. The increasing demand for still larger engines has led to the recent erection by the author's firm of new works for building engines of this kind up to any power that may be required.

Standard Make of High Speed Engines.—The small sizes up to about 15 horse power are all single crank with single or tandem compound cylinders. The smaller compounds up to 300 horse power are of the two-cylinder "Crescent" type, as shown in Figs. 2 and 3. The cranks are opposite, and a single eccentric actuates the slide valves. The oil pump is an oscillating one, worked off the eccentric, and its oscillation performs the

necessary valve action on a surface at the bottom of the pump. The pumps are, therefore, most simple, without either valves or packing to get out of order. The engine is, indeed, throughout as simple in every detail as it is possible to make it. The oil is usually drawn from the bottom of the engine casing, through strainers which can be easily removed, into pipes leading to all the bearings; but occasionally, as at Bedford, at the Charing Cross and Strand Electricity Supply Station, at Leeds and at other places, a complete series of reservoir tanks has been fitted, supplied by separate and independent pumps. Pure mineral oil is used at a pressure of about 15 pounds per square inch. These two crank engines are made triple expansion when necessary by adding two single-acting high pressure cylinders, tandem with the other two; and this forms one of the simplest and most effective designs that can be devised for high speed triple expansion engines. Formerly the engines were fitted with outside glands only where they were used with condensers on board ship; but recently this design has been adopted throughout, in order to keep the patterns constant, and also to prevent the trouble which water from the glands causes with some kinds of oil. The oil question becomes of serious importance in central electric stations fitted with condensers, especially where water tube boilers are used.

Vibration.—For large central stations situated in densely populated neighborhoods, the design of the steam engine employed has been determined largely by the single question of vibration. The amount of vibration which will cause a nuisance is small; and several London electric stations have incurred serious losses on account of vibrations, which at the engines themselves seem inconsiderable. Having had to approach the subject of vibration in high speed engines for land and marine purposes simultaneously, the writer was at first led astray by assuming an equality in the conditions which really did not exist. The vibrations in the engines themselves may be classed as follows: First, those due to vertical changes in the position of the center of gravity of the moving parts; second, those due to couples produced by the changing momentum in the several lines of moving parts;

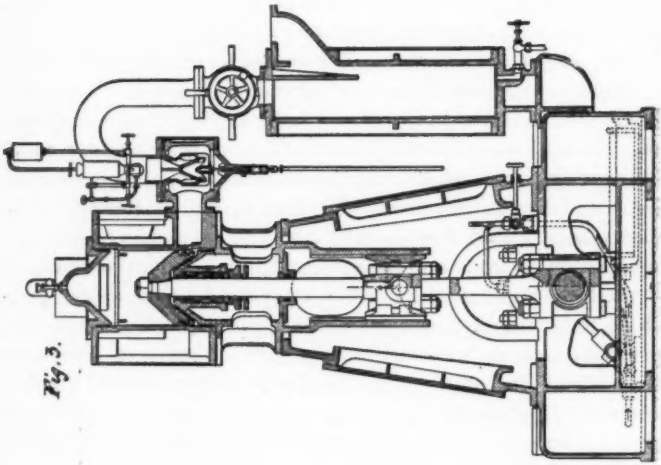


Fig. 3.

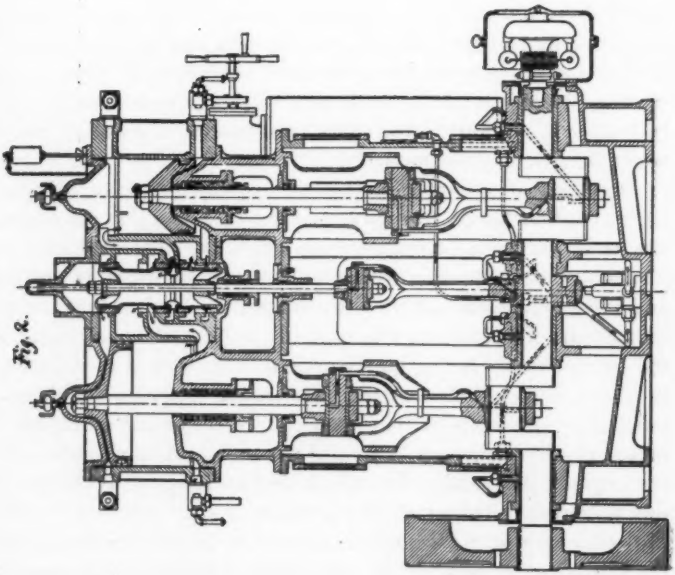


Fig. 2.

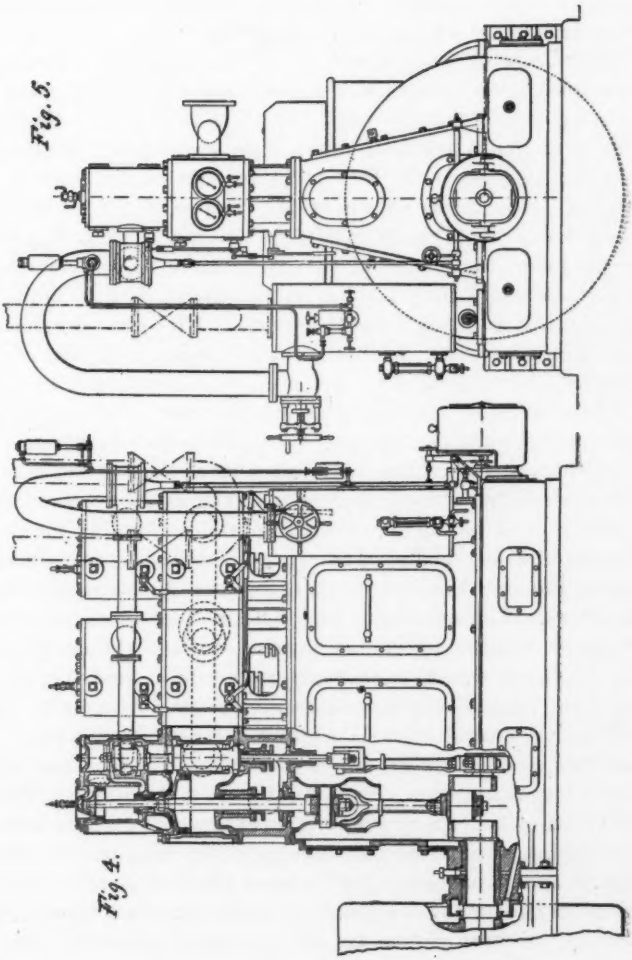


Fig. 5.

Fig. 4.

and third, those due to the obliquity of the connecting rod producing retardation and acceleration of the moving parts in each line, which occur twice in each revolution.

The "Crescent" engine, with cranks opposite, Figs. 2 and 3, is practically balanced against the first class of vibrations; but it has a big couple, and also vibrations of the third class. Engines with three cranks at equal angles, Figs. 4 and 5, are practically balanced as regards the first and third classes, but have large couples. Now it was shown by Mr. Yarrow at the Institute of Naval Architects (Transactions 1892, Volume 33, page 213), that by balancing the effects of the couples the heavy vibrations could practically be got rid of in torpedo boats and similarly built vessels with high speed engines. This was successfully done with a few small weights in the four-cylinder engines of the *Spitfire* and *Swordfish*, Fig. 1, as previously mentioned.

The conclusion, therefore, was hastily drawn that engines for land purposes could be similarly dealt with; and an engine was built which was absolutely balanced as far as the first and second classes of vibrations were concerned, but experience showed that buildings took up the higher speed vibrations forming the third class; and it was finally found necessary to fit a return connecting rod to one line of cylinders, in order to obliterate these vibrations. This expedient gave both in theory and on trial a perfect non-vibrating engine in the station. Three-cylinder engines, however, with equal angle cranks, Figs. 4 and 5, in which the third class of vibrations were practically obliterated, were working in central stations without difficulty from vibration; and further investigation led to the conclusion that buildings respond to the quicker vibrations, but are practically indifferent to the heavy but slower vibrating couples which give such trouble in ships. The three-cylinder engine with equal angle cranks, Figs. 4 and 5, has consequently been adopted as the standard above 200 horse power for central stations in densely populated districts. Similar engines are also used where a uniform turning effort is especially required; though this object can, of course, be attained to any desired extent in other kinds of engines also, by providing a sufficiently heavy fly wheel.

TABLE IV.—TRIALS OF BELLISS 200 HORSE POWER, QUICK REVOLUTION, SELF-LUBRICATING ENGINES, CONDENSING.

	Sunderland Electric Supply Engine, tested by Professor Kennedy. Standard E.C. 9. Cylinders 12¼ and 20 inches diameter, stroke, 9 inches.					Cheltenham Electric Light Engine, tested subsequently. Standard E.C. 9. Cylinders 12 and 20 ins. diam., stroke, 9 ins.			
Load.	Maximum.	Normal full.	Three quarters.	Half.	One-quarter.	Normal full.	Three quarters.	Half.	One-quarter.
Mean effective pressure referred to low pressure cylinder, pounds	42.3	37.6	28.6	20.0	9.7	36.1	.....	20.6	10.4
Mean revolutions per minute	364.0	365.0	364.5	363.9	363.8	365.5	.....	361.0	361.5
I.H.P.	217.5	193.6	147.1	102.7	49.8	185.7	.....	104.8	53.1
B.H.P.	209.5	186.0	140.6	97.0	44.5	176.8	.....	97.4	44.2
Mechanical efficiency, per cent.	96.3	96.1	95.2	94.4	89.3	95.2	.....	93.0	83.2
Water per hour, total, pounds	3,772	3,383	2,628	1,920	888.5	3,301	.....	1,939	987.9
per B.H.P., pounds	18.0	18.2	18.7	19.8	20.0	18.6	.....	19.9	22.3
	Coupled to Continuous Current Parker Dynamo.					Coupled to Alternator.			
Mean effective pressure referred to low pressure cylinder, pounds	36.0	24.2	19.2	10.5	2.2	28.4	23.0		
Mean revolutions per minute	367.6	368.3	362.6	365.2	364.8	350.2	351.0		
I.H.P.	186.7	129.4	98.2	54.1	11.6	144.8	114.4		
E.H.P.	168.6	115.1	83.8	40.9	.....	126.8	98.5		
Combined efficiency, per cent.	90.3	88.9	85.3	75.6	.....	87.5	86.1		

Advantages of Forced Lubrication.—For all kinds of engines the plan of forced lubrication gives the same advantages; namely, automatic lubrication, noiselessness, economy and freedom from wear. This last is due to the working surfaces being kept apart by the film of oil forced between them. Although generally the pressure per square inch on the bearing itself is far in excess of the oil pressure used, yet the relaxation of pressure on the return stroke in a double-acting engine permits the oil at these times to be driven between the metal surfaces; and during the fraction of a second occupied by the acting stroke the film of oil cannot be squeezed out. This might indeed be readily taken for granted, and is clearly proved by the absence of wear in the large number of engines already built. It is at least obvious that the oil is in the best position to take advantage of the momentary relaxation of pressure between the surfaces, if it is itself under a pressure sufficient to push it in between the brass and the journal, so as to flood the bearing completely. If the

oil is supplied by gravity alone, under the head usually given in double-acting engines, there is not sufficient time for permitting it to penetrate to any distance. In a single-acting engine under constant thrust, no such film is possible. In both the latter cases, the journal will, of course, be greased; but if friction and consequent wear of the journal are to be absolutely prevented, such a film of oil as the forced lubrication provides between the journal and brass is essential. The better the body of the oil, the less chance will there be of effective lubrication without adequate oil pressure. To show how the oil film should effect the economy, reference may be made to a paper by Professor Robert H. Thurston, published in "Engineering" (January 18, 1889, page 69), in which the friction in an engine with balanced slide valve is subdivided as follows: Main bearings, 47 per cent.; piston and rod, 32.9; crank pin, 6.8; crosshead and wrist pin, 5.4; valve and rod, 2.5; and eccentric strap, 5.3 per cent. The friction of piston and rod here probably includes that of the guides, which are lubricated under pressure in the engines now described; and in addition to this it will be seen that the journal friction, which can be reduced by oil under pressure, amounts to nearly 65 per cent. of the whole. When it is borne in mind that in an ordinary engine, working at one-quarter of its full power, about 50 per cent. of the power developed is wasted in friction, it is clear that the effect on the economy by the reduction of journal friction should prove considerable at low loads; and with these double-acting self-lubricating engines, as compared with single-acting engines, it is certain that this is so. It was first pointed out by Mr. Alexander Siemens in a paper read before the North of England Institute of Mining Engineers (November 24, 1894, page 212), in which he compared the results of the first Belliss 300 horse power self-lubricating engine with a Willans engine of similar power, the two working alongside each other at his Charlton Works; his results showed that the gain due to the diminished friction increased considerably as the loads were reduced.

In dealing with high speed engines, it is impossible to avoid referring to the admirable work which has been done by Messrs.

Willans & Robinson in determining the conditions for economical working under various circumstances. Their trials, however, were made with single-acting engines; and although the results in general will apply to any engine, the reduction of friction in the double-acting self-lubricating engine should qualify them to some extent in detail. If the lubrication is accomplishing the purpose for which it is intended, the efficiency of the engine provided with forced lubrication ought to stand out high; and that this is so for all loads has been proved by results from some hundreds of engines. By the courtesy of Professor Kennedy the author is enabled to give in Table IV the results of a trial made by him of one of these engines, supplied to the Sunderland Corporation Electric Supply Station, which will serve as an example. Here the engine efficiency at maximum load, it will be noted, works out at 96.3 per cent. The results are also plotted as a diagram in Fig. 6. The following comment upon the figures in the Sunderland tests was added by Professor Kennedy: "The most singular point about them is the extraordinary high brake efficiency of the engine, which is altogether much higher than anything I have previously found. I do not know the special cause of this. I have been extremely suspicious of the figures, and have had everything checked repeatedly. The different figures taken at different periods are quite consistent with each other, and there is nothing in the records to suggest error, except the figures themselves. I can only place these on record, without saying more about them." There is no doubt that the efficiency is remarkably high; but the conditions, as already pointed out, all tend in this direction, and similar results have been proved over and over again with the self-lubricating engines tested at the author's works. In order, however, to establish the results obtained by Professor Kennedy, a further trial was conducted with a similar engine made for the Cheltenham electric light station from the same drawing as that at Sunderland; and it will be seen that the results given in Table IV, and plotted in Fig. 8, entirely bear out those of the other trials. The high efficiency that can thus be obtained makes itself felt in the economical working of the engine; and as it is due to an absence

of friction, a far greater saving will probably arise from the diminished necessity for adjustment and repair on account of wear. In the writer's opinion there is too much difficulty in obtaining the necessary accuracy in indicating a high speed engine to render efficiency alone a useful standard of comparison. The consumption of steam for work done is what the customer looks at, and results given per indicated horse power, which take no account of the heavy losses through friction, are useless in comparing engines of different kinds. It will be seen from Fig. 7, giving the curves of the combined efficiency and consumption in the subsequent tests of the Sunderland engine coupled to a continuous current dynamo, that the previous brake tests are fully borne out. These subsequent tests were made immediately after the others, in the presence of Professor Kennedy and Mr. Snell, the electrical engineer to the Sunderland Corporation. The results throughout are undoubtedly good; and, for the sake of comparison, curves have been added showing the consumption and efficiency of a Willans engine of about the same power combined with a Holmes dynamo in a trial made by Professor Kennedy, and reported in "Engineering" (June 2, 1893, page 783).

Governing.—Amongst the many admirable papers emanating from Messrs. Willans and Robinson on the subject of high speed engines is a recent paper read to this Institution by Captain Sankey (Proceedings, 1895, page 154), in which governing by expansion valve is compared with ordinary governing by throttle valve. This important contribution to the subject is chiefly remarkable for the tendency of the results presented to displace the expansion valve governor from the high position it has hitherto held as an economical appendage for reducing power. The disadvantages due to the higher initial pressure with consequent leakage, the frictional loss due to compression, and the increased losses due to liquefaction, are clearly pointed out; and the resulting efficiencies of the two modes of governing, especially when determined by work done and not by indicated horse power, are shown to be not greatly in favor of the expansion valve governor. Expansion gear of this sort is also far more liable to wear; and a small amount of wear, or of wrong adjust-

ment after repair, might lead to a steam distribution yielding at low load considerably worse economy than that obtained in the official trial at the works. As in the case of economical results, the comparative efficiency of the two methods of governing will also depend in detail somewhat on the kind of engine; and for this reason the trials that have been made by the author for determining the value of the two kinds of governor with the self-lubricating engine may be of interest. The results given by Captain Sankey are also based entirely on the indicated horse power; but as the output of the engine is largely modified by frictional and other losses due to the action of the governor itself, the indicated horse power results are of little practical value. The circumstance that the "Crescent" engine, Fig. 2, is arranged with both the valves driven by a single eccentric naturally led in the direction of expansion governing, owing to the ability of this governor to act simultaneously on both high and low pressure valves. Trials made in 1891 with a number of sets of dynamo machinery of about 80 horse power, constructed by the writer's firm for the Cunard steamships *Campania* and *Lucania*, gave excellent results as far as governing went; but at low power the results in respect of economy and efficiency were by no means as good as anticipated; and although in consequence of its effective action the use of the governor was continued, the poor economical results led to special trials being made further on for determining this point more exactly. So far as the governing itself is concerned, since the above machinery was built, the throttle governor with ordinary flywheel has been made by the reduction of friction to give exceedingly steady results, with a permanent variation of only 2 to 3 per cent., and a momentary run up to about 10 or 12 per cent. when all the load was suddenly thrown off. With the ordinary flywheel it is not possible to get much finer governing without introducing a tendency to hunt. The effect of a large flywheel permits the fitting of a much more sensitive governor; and with a flywheel of suitable dimensions governing by throttle can be made as fine and steady as may be required. Alternators of ordinary design have, of course, in themselves quite enough

flywheel effect for enabling the usual engine flywheel to be dispensed with; and with these there is no difficulty in keeping the run-up below the 5 per cent. with permanent variation of 2 per cent. The reputation of the expansion valve governor has been much increased by the value set upon it in the United States, where it is almost universally used; but this fact is largely qualified by a consideration of the high flywheel effects employed in conjunction with the governor in order to obtain the maximum results. The following Table V, gives a few typical examples for enabling a comparison of these flywheel

TABLE V.—ENERGY STORED IN FLYWHEEL AND REVOLVING PARTS OF DYNAMO PER ELECTRIC HORSE POWER AT FULL LOAD, FOR VARIOUS SERVICES.

	Foot tons.
Ordinary high speed engines for electric lighting with continuous current dynamos	0.2 to 0.3
Ditto, with heavy alternator	1.5 to 3.5
Electric traction, Continental example	2.0
Montreal Street Railway	4.0
Brooklyn Electric Tramway	4.7

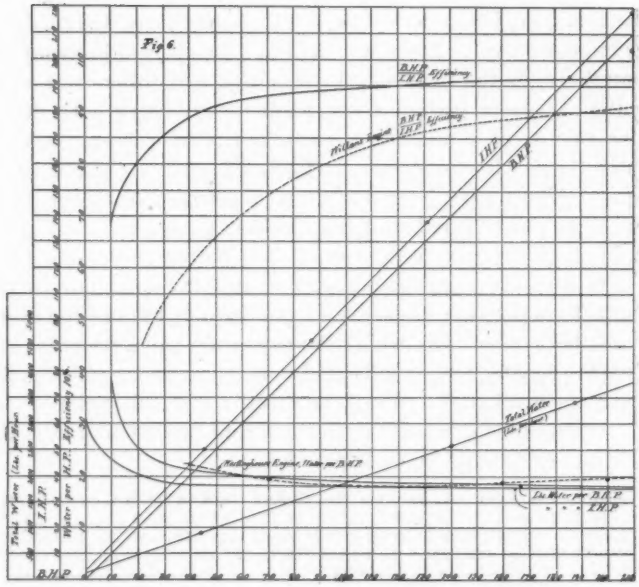
effects to be made for various services. For the Waterloo and City Railway, where it is desired to light the train steadily direct from the motor currents, a flywheel of about 5½ tons has been fitted on each of the 300 horse power sets in order to obtain the required results, namely, permanent variation not exceeding 1¼ per cent., and momentary not exceeding 2½ per cent. when all the load is suddenly removed. As far as governing is concerned, therefore, it may be allowed that the advantage, if any, is on the side of the throttle valve governor, because it is equally powerful in governing, far less liable to derangement and wear, and much easier to adjust.

In respect of economy, the matter will naturally be looked at from two points of view: firstly, for electric lighting and electric power supply, where the maximum economy is required at about full load; and, secondly, for electric traction, where the normal load will probably be a much smaller fraction of the full load than in electric lighting. For electric lighting and power supply there is no question in the author's mind as to the superior efficiency of the throttle valve governor. For electric traction,

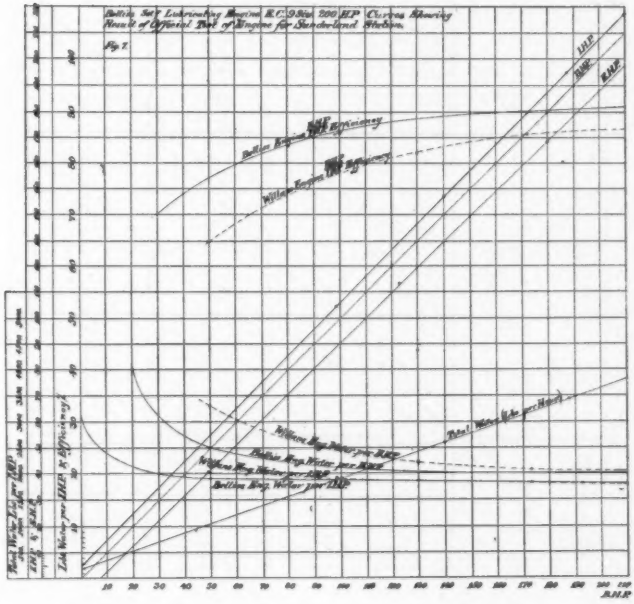
his experiments seem to show that with the double-acting self-lubricating engine there is little, if any, benefit to be derived from the expansion valve governor; and this benefit will probably be neutralized by the mechanical difficulties, which the extra wear on the expansion governor will subsequently entail. To determine this point a number of experiments have been made, of which the results are shown in Table VI, and in the curves in Fig. 9. These trials were made with a self-lubricating engine of 250 horse power, fitted with an expansion governor actuating an eccentric common to both valves. The dotted curves show the results with the expansion governor, and the solid curves the results from the same engine when governed by the throttle valve. It will be noticed that, whilst the expansion valve governor has a slight advantage when indicated horse power is considered, the advantage is all on the side of the throttle valve when the output or electric horse power is considered; and this, of course, is the only matter of importance in practice.

TABLE VI.—TRIAL OF BELLISS 250 HORSE POWER QUICK-REVOLUTION SELF-LUBRICATING ENGINE, CONDENSING. STANDARD E.C. 10. CYLINDERS 12 INCHES AND 20 INCHES BY 10 INCHES. WITH EXPANSION GOVERNOR IN ACTION, *I. E.*, EXPANDING. STEAM PRESSURE, 150 POUNDS.

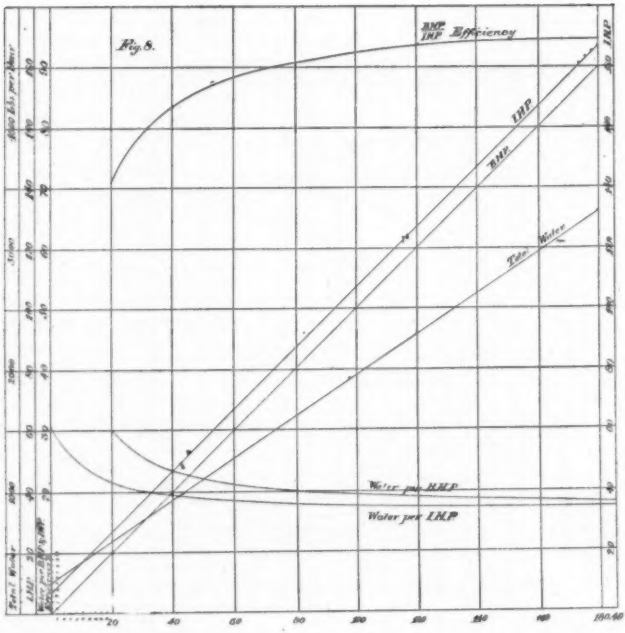
	Full load.	Five-eighth load.	One-third load.	Quarter load.
Mean effective pressure referred to low pressure cylinder	41.05	27	16.4	12.4
Mean revolutions per minute	370	373	380	380
indicated horse power	249.9	161	99	75.34
electrical horse power	213	132.8	77.8	53
Combined efficiency, per cent	88.3	82.4	78.5	70.3
Total water, pounds per hour	4,579	3,041	2,209	1,818
Pounds of water per electrical horse power	21.5	22 9	28 5	34.3
WITH EXPANSION GOVERNOR OUT OF ACTION, *I. E.*, THROTTLING. STEAM PRESSURE, 150 POUNDS.				
Mean effective pressure referred to low pressure cylinder	40.15	25.9	15.7	10.9
Mean revolutions per minute	370	370	380	382
indicated horse power	235.4	152.16	95	66.25
electrical horse power	213	132.16	77.8	53
Combined efficiency, per cent	90.4	86 8	81.9	80
Total water, pounds per hour	4,473	2,871	1,992	1,505
Pounds of water per electrical horse power	21	21.72	25.6	28.4



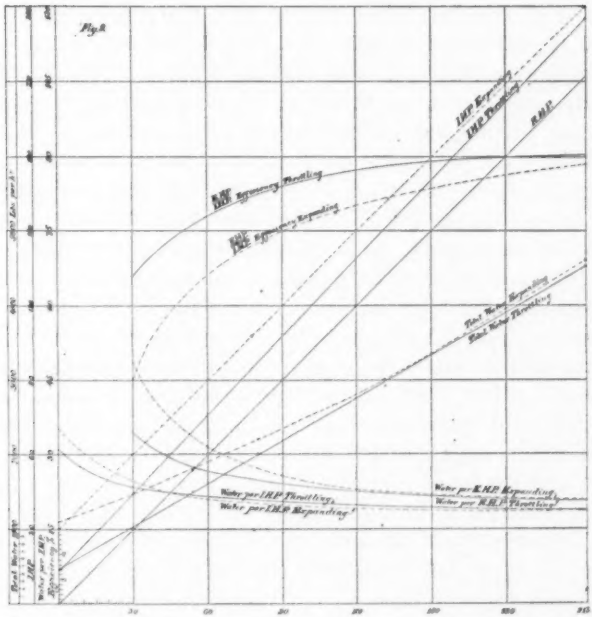
Total water.		Efficiency.			Pounds of water per horse power hour.			
B.H.P.	Lbs. per hour.	I.H.P.	B.H.P.	B.H.P. / I.H.P.	I.H.P.	Water.	B.H.P.	Water.
210	3,780	217.8	210	96.4	217.8	17.34	210	18
200	3,640	207.8	200	96.25	207.8	17.5	200	18.2
180	3,290	187.3	180	96.1	187.3	17.55	180	18.3
160	2,950	167	160	95.9	167	17.65	160	18.42
140	2,600	146.8	140	95.4	146.8	17.7	140	18.56
120	2,250	125.25	120	95	126.25	17.8	120	18.75
100	1,900	106	100	94.5	106	17.91	100	19
80	1,560	85.6	80	93.5	85.6	18.25	80	19.5
60	1,216	65.25	60	92	65.25	18.57	60	20.26
40	860	45.18	40	88.75	45.18	19	40	21.5
20	515	25	20	80	25	20.6	20	25.75
10	340	15	10	66.75	15	33	10	34



I.H.P.	E.H.P.	E.H.P. / I.H.P.	Pounds water per	
			Hour.	E.H.P.
		per cent.		
187.3	169	90.3	3,290	19.46
167	149.75	89.6	2,950	19.7
146.8	130.5	88.8	2,600	19.92
126.25	111	87.9	2,250	20.87
106	91	85.8	1,900	20.57
85.6	71.5	83.5	1,560	21.81
65.25	51.75	79.3	1,216	23.5
45.18	32	70.8	860	26.8



Pounds of water per horse power hour.		B.H.P. / I.H.P. efficiency.				Total water.	
I.H.P.	Water.	B.H.P.	Water.	I.H.P.	B.H.P.	Efficiency.	B.H.P.	Pounds water per hour.
						per cent.		
188.5	17.58	180	18.4	188.5	180	95.5	180	3.312
168.5	17.65	160	18.58	168.5	160	95	160	2,975
148.5	17.7	140	18.75	148.5	140	94.5	140	2,630
128.3	17.8	120	19.0	128.3	120	93.5	120	2,285
108.3	18.1	100	19.6	108.3	100	92.4	100	1,960
88.3	18.25	80	20.15	88.3	80	90.6	80	1,612
68.3	18.68	60	21.25	68.3	60	87.8	60	1,275
48.3	19.55	40	23.6	48.3	40	82.8	40	945
28.3	21.2	20	30.0	28.3	20	70.8	20	600
8.3	31.35	...	...	...	...	...	0	260

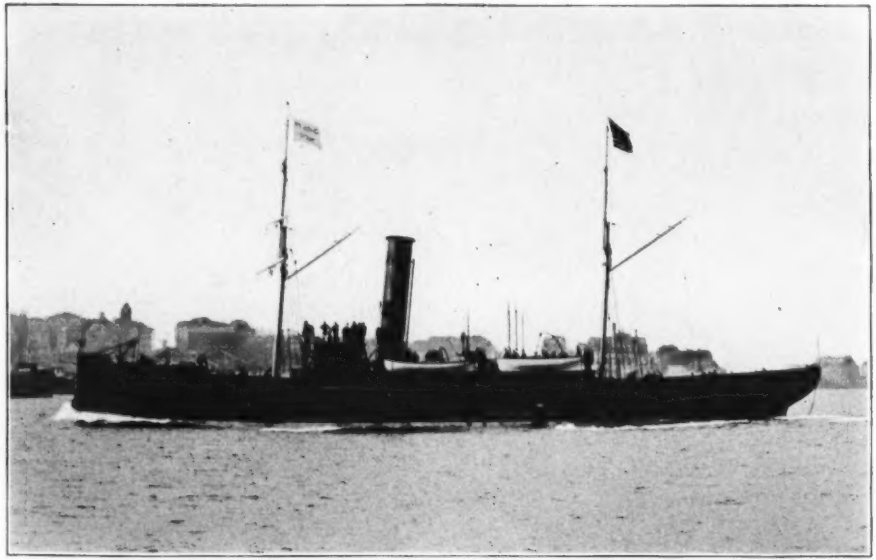


E.H.P.	Pounds of water per I.H.P.				E.H.P.	E.H.P. / I.H.P. efficiency.			
	Throttling.		Expanding.			Throttling.		Expanding.	
	I.H.P.	Water.	I.H.P.	Water.		I.H.P.	Effic'cy.	I.H.P.	Effic'cy.
213	235 4	19	240.9	19	.....	.....	*per cent.*	.....	*per cent.*
180	200	19.25	208.75	18 9	213	235.4	90.4	240.9	88.3
150	169	19.5	179	18.7	180	200	90	208.75	86.5
120	138.5	19.8	150	18 9	150	169	88.8	179	83.8
90	107.5	20.3	120.5	19.6	120	138.5	86.75	150	80
60	76.5	21.3	91	21.1	90	107.5	83.75	120 5	74.8
30	45.5	23.6	61.5	24 65	60	76.5	78 5	91	66
0	14	30.7	32	35.2	30	45.5	66	61.5	43.8

E.H.P.	Pounds of water per E.H.P.		E.H.P.	Total water per hour.	
	Throttling.	Expanding.		Throttling.	Expanding.
213	21	21.5	213	4.473	4,579
180	21.4	21.95	180	3,850	3,950
150	22	22.5	150	3,300	3,375
120	22.83	23.65	120	2,740	2,840
90	24.33	26.22	90	2,190	2,360
60	27.16	32	60	1,630	1,920
30	35.83	50.5	30	1,075	1,515
.....	.....	.....	0	430	1,125

From all the diagrams it will be seen that the characteristic curve of water consumption for the Belliss engine is more horizontal than those for single-acting engines. This is due, as already pointed out, to the action of the forced lubrication in reducing the amount of friction, and consequently the amount of steam used per brake horse power. In order to elucidate this point more fully, there is added in Fig. 6, for comparison with Sunderland, as shown by the dotted lines, the consumption per brake horse power for a Westinghouse engine of about the same power, fitted with an expansion valve governor, for which the data are taken from the proceedings of the Institution of Civil Engineers, Vol. CXIV, page 68. It will again be seen that, while with the expansion governor in the Westinghouse engine the result at half load is better than at full load, it is not better than the result obtained at half load with the throttle governor in the Belliss engine, which has, moreover, a decided advantage at full and low loads.

For the sake of further comparison another curve has also been added to Fig. 6, showing the efficiency of the Willans 150 horse power engine, reported in the same volume of the Civil Engineers, pages 89 and 90.



U. S. REVENUE CUTTER "MANNING."

THE CONTRACT TRIALS OF THE U. S. REVENUE CUTTERS *MANNING* AND *McCULLOCH.*

By First Assistant Engineer C. A. McAllister, U. S. R. C. S.

Revenue Cutter No. 2, the *Manning*, and Revenue Cutter No. 3, the *McCulloch*, are single screw, composite vessels; the first was built by the Atlantic Works, of East Boston, Mass., at a contract price of $159,951, and the latter was built by the Wm. Cramp & Sons Ship and Engine Building Co., of Philadelphia, Pa., at a price of $196,750, which did not include the cost of the distilling apparatus, clothing and lagging, spare parts of machinery, and the sails, awnings, boats and outfit. The hulls of these vessels are of entirely different dimensions, that of the *McCulloch* being the larger, but the steam machinery of each is practically a duplicate of the other.

For purposes of comparison, the accounts of the trials and the description of the machinery will be combined, while the other data will be given under separate headings.

MANNING.

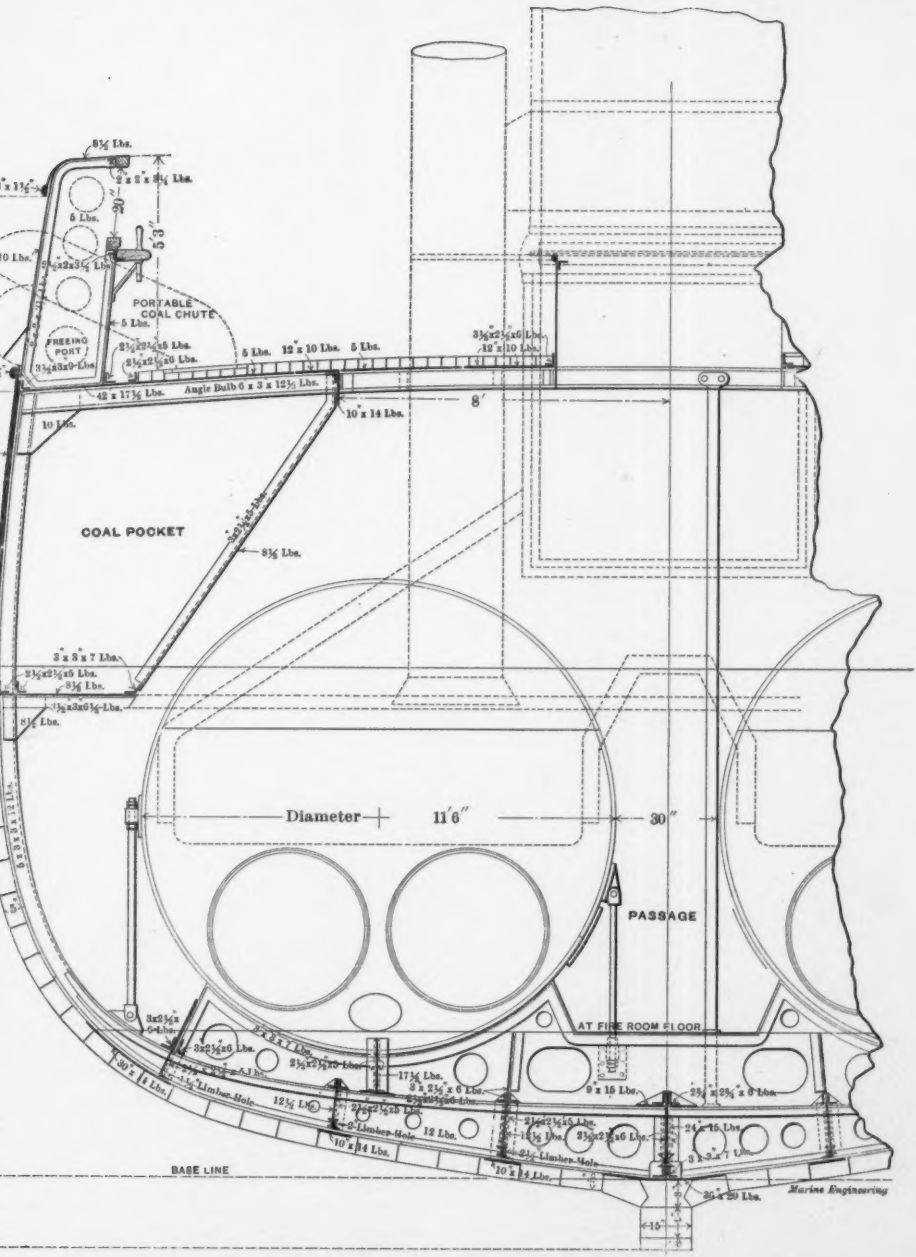
This vessel is intended for service on the Atlantic Coast, with headquarters at Boston, Mass. She is of composite build, with steel framing and plating above water line, and wooden planking sheathed with copper below the water line. As the contract for the *Manning* was awarded June 30, 1895, she is, therefore, the first composite Government vessel of modern construction to be built in this country. Her rig is that of a topsail schooner, and she carries sufficient sail power to be of assistance in a strong breeze of wind. The stem is ram-shaped and is fitted with a port for a 15-inch torpedo tube. The vessel throughout is of such construction as would enable her to be transformed into a fast and serviceable gunboat in time of war. With a battery of six 4-inch rapid-firing breech-loading rifles and the usual secondary battery, she would prove, on account of her speed of 17 knots, a more efficient gunboat than those of *Vicksburg* class.

The framing and plating above the water line is of mild open-hearth steel, the physical requirements for which were a tensile strength of not less than 55,000 pounds per square inch, and an elongation, in a uniform length of 8 inches, of not less than 25 per centum. The transverse frames, except at the extremeties of the vessel, are of Z-bars, $5 \times 3 \times 3$ inches by 12 pounds per linear foot, and they are spaced 24 inches between centers. The stem, stern post, rudder frame and rudder plating are of manganese bronze. The main deck beams are formed of angle bulbs, 6×3 inches by $12\frac{1}{3}$ pounds per foot, with a camber of 7 inches in 32 feet. The outside plating is of 14-pound plate, the sheer stráke being double for a length of 180 feet. The outside planking is of Oregon fir, 5 inches in thickness on the frames of the vessel and reduced over the tie plates and other plating to make fair work. The planking is secured to the frames of the vessel by through bolts of Tobin bronze $\frac{15}{16}$ inch in diameter in shank. The heads of the bolts are let into the planks on the outside, the holes being filled by wooden plugs. The nuts on the inside are set up on thin cast iron washers, with hemp grommets well soaked in red and white lead underneath. The upper edge of the top strake is protected by a beveled angle iron, riveted to the plating.

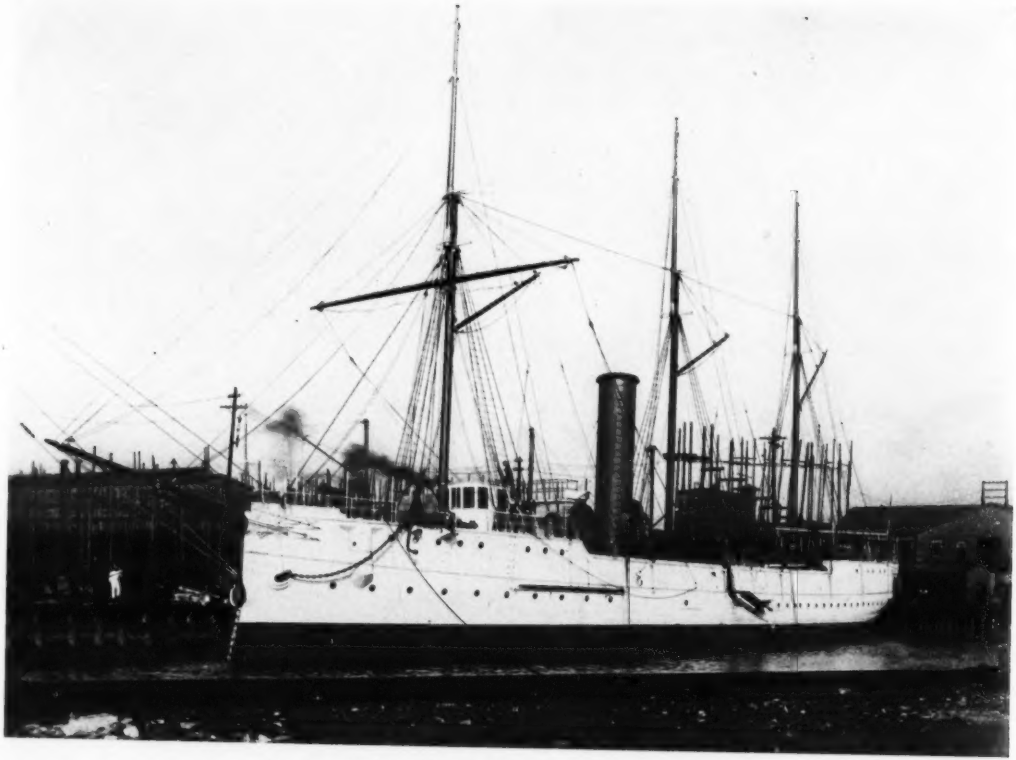
There are accommodations for a crew of about fifty men. The officers' quarters are aft, and are roomy, well lighted and ventilated. The petty officers' and crew's quarters are forward on the berth deck. In the house on deck are located the ship's galley, ice chests, carpenter shop, engineer's workshop, officers' bath room and lavatory, and a lamp room. The following are some of the dimensions of the hull:

Length over all, feet and inches	205– 6
between perpendiculars, feet	188
Beam, extreme, at L.W.L., feet and inches	32–10
Draught, mean, normal, feet and inches	12– 3
Displacement at above draught, tons	980
Area of immersed midship section, square feet	304
Tons per inch draught, at L.W.L.	10 35
Co-efficient of displacement, block	.486
midship section	.799
Wetted surface, square feet	6,903

FREEING PORT
COAL
at frame 50.
14'
12 3½"



CROSS SECTION OF REVENUE CUTTER "McCULLOCH."



U. S. REVENUE CUTTER "McCULLOCH."

McCULLOCH.

The *McCulloch* is the largest Revenue Cutter ever built, and is intended for service on the Pacific Coast, with headquarters at San Francisco, Cal. As she will have to make annual cruises to the Bering Sea and Northern coast of Alaska, it was necessary to have a vessel of large bunker and hold capacity in order to carry sufficient coal and stores. She is rigged as a three-masted schooner with a square foresail, and has a bowsprit and jibboom, which will enable her to carry considerable headsail while cruising. In details of construction she is similar to the *Manning*, but her deck arrangement is entirely different, inasmuch as she has no deck house, but instead, has poop and forecastle decks, which provide large quarters for the commanding officer aft and protection for the crew forward. Like the *Manning*, the stem, stern and rudder frames and rudder plating are of manganese bronze. The casting for the entire stem is in one piece, and is the largest ever made in this country, as its total weight is 14,000 pounds. The stem is fitted with a port and shutter for a 15-inch torpedo tube. The regular armament will consist of four 6-pounder rapid-firing Hotchkiss rifles mounted in sponsons, two forward and two aft. The vessel is of such construction, however, that eight 4-inch rifles could be readily fitted, should it become necessary to transform her into a gunboat. The following are some of the principal designed dimensions of the hull.

Length between perpendiculars, feet	200
over all, feet	219
Beam, extreme, at L.W.L., feet and inches	33-4
Draught, mean, normal, feet	14
Displacement at this draught, tons	1,280
Area of immersed midship section, square feet	363
Tons per inch of draught, at L.W.L.	11.47
Co-efficient of displacement, block	.510
midship section	.850
Wetted surface, square feet	8,188

MAIN ENGINES, *MANNING* AND *McCULLOCH.*

There is for each vessel one vertical, inverted, direct-acting, triple expansion engine with cylinders 25, 37.5 and 56.25 inches

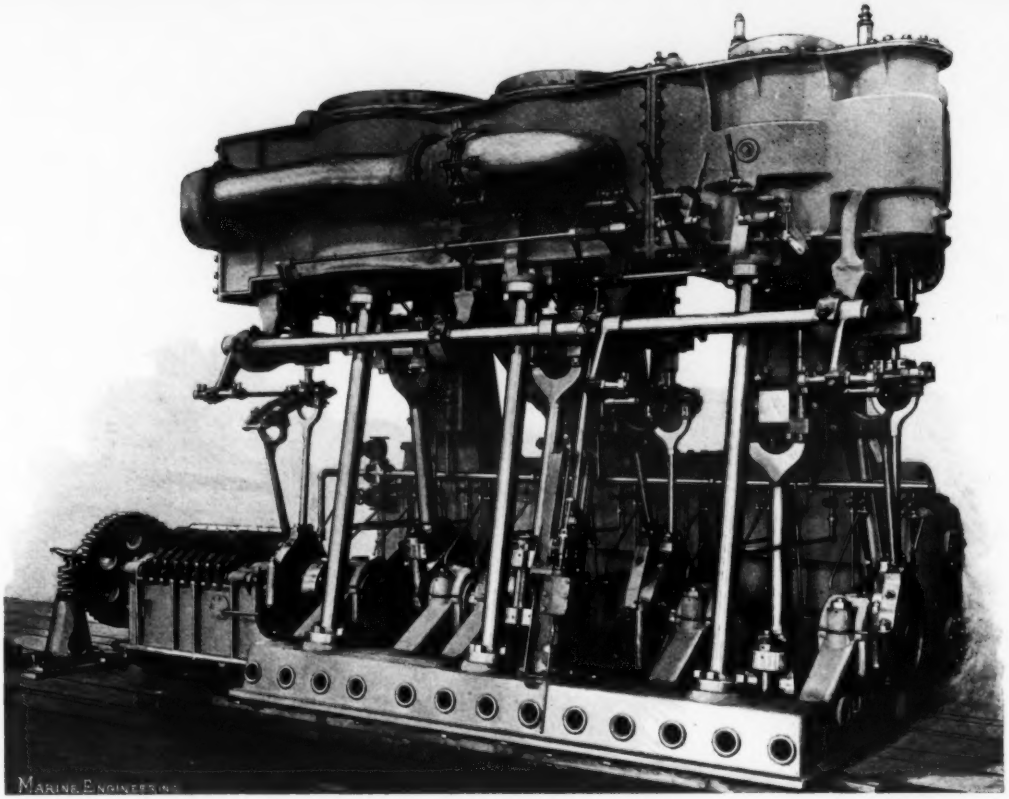
in diameter, and a common stroke of 30 inches. Each cylinder is fitted with a hard cast iron liner, and the I.P. and L.P. cylinders are steam-jacketed. The valve gear is of the Stephenson link type, working a piston valve for the H.P. cylinder, and double-ported slide valves for the I.P. and L.P. cylinders.

The I.P. and L.P. valves are assisted by counterbalance cylinders which connect directly to the main condenser. The cut-off for each valve is adjustable by means of slotted reversing arms.

The main pistons are of cast steel, conical, and each is fitted with two hard cast iron packing rings, $\frac{5}{8}$ inch wide by $\frac{3}{4}$ inch thick. The high and intermediate pressure packing rings are each made in six, and the low pressure rings, in eight sections. The joints between all sections are made with brass tongue pieces. Each cylinder is supported at the front by a forged steel column 6 inches in diameter. At the back, they are supported by short cast iron columns which are cast with the sections of the main condenser. Hollow guides for water circulation are bolted to the back columns. The bed plate is of cast iron, in one piece. The top of the engine foundation is formed of one steel plate, $\frac{3}{4}$ inch thick, which extends aft and forms the top of the thrust bearing foundation.

The reversing gear is of the ordinary direct-acting type, consisting of a steam cylinder bolted to the bed plate, and connecting to double arms on the reverse shaft. For the *Manning*, this cylinder is 12 inches in diameter by 12.5 inches stroke; on the *McCulloch*, it is 10 inches in diameter by 18 inches stroke. On the *Manning* there is, in addition to the steam reversing gear, a screw hand gear, worked by a large hand wheel secured to the high pressure cylinder casing above the working platform. There is a hand turning gear, operated by a ratchet lever in conjunction with a worm and wheel secured to the shaft aft of the thrust bearing.

All materials used in the construction of these engines were most carefully selected and inspected. Samples cut from all iron castings were required to show a tensile strength of not less than 18,000 pounds per square inch. Steel castings, a tensile strength of not less than 60,000 pounds per square inch, an elongation of


MARINE ENGINEERING

15 per centum in 8 inches, and to stand bending cold to an angle of 120 degrees without fracture. The steel for piston rods, connecting rods, valve stems and crossheads, was required to show a tensile strength of not less than 80,000 pounds per square inch, an elongation of 25 per centum in 2 inches, and to stand bending double after being quenched in water from a cherry red heat. Steel for the other forgings, such as shafting, front columns, etc., a tensile strength of 60,000 pounds, an elongation of 25 per centum in 8 inches, and to bend double after being quenched from a cherry red heat. Condenser tubes were required to be of such quality that samples could be flattened out either hot or cold, and bent double, flat on themselves without sign of fracture. The steam machinery of these vessels was designed under the supervision of Captain John W. Collins, the Engineer-in-Chief of the Revenue Cutter Service.

The following are some of the principal dimensions, ratios, etc., of one engine.

Number of cylinders	3
Diameter of cylinders, H.P., inches	25
I.P., inches	37½
L.P., inches	56¼
Stroke of pistons, inches	30
Valves, diameter of H.P., inches	16
length of I.P., feet and inches	2–11 11/16
width of I.P., feet and inches	3– 0½
length of L.P., feet and inches	3– 4⅝
breadth of L.P., feet and inches	4– 8
diameter of I.P. balance piston, inches	5½
effective area of I.P. balance piston, square inches	21.35
diameter of L.P. balance piston, inches	9
effective area of L.P. balance piston, square inches	61.21
Area H.P. steam ports, maximum opening, inches, top	59.96
bottom	64.12
exhaust ports, maximum opening, top and bottom, inches	76.00
I.P. steam ports, maximum opening, inches, top	101.00
bottom	108.00
exhaust ports, maximum opening, top and bottom, inches	128.00
L.P. steam ports, maximum opening, inches, top	202.00
bottom	220.93
exhaust ports, maximum opening, top and bottom, inches	293.87
Valve stems, H.P., diameter, inches	2

Valve stems, H.P., diameter, through valve, inches	1½
I.P. and L.P., diameter, inches	2½
through valve, inches	2⅝
Main steam pipe (9 inches in diameter), area cross section, square inches	63.61
Exhaust pipe from I.P. to L.P. (14½ inches in diameter), area cross section, square inches	165 13
Exhaust pipe to condenser (19 inches in diameter), area cross section, square inches	283.53
Volume swept by H.P. piston per stroke, cubic feet	8.52
I.P. piston per stroke, cubic feet	19.17
L.P. piston per stroke, cubic feet	43.14
Ratio of net area of H.P. to I.P. piston	1 : 2.26
I.P. to L.P. piston	1 : 2.25
H.P. to L.P. piston	1 : 5.06
Piston rods, diameter, inches	5
length from piston to crosshead, feet and inches	4– 1¼
Connecting rods, length, center to center, feet and inches	6– 3
diameters of upper and lower ends, inches	5 and 6½
Crossheads, surface (go-ahead), square inches	208
Crosshead pins, diameter and length, inches	5¾ and 6½
Crank shaft, diameter, inches	10½
coupling discs, diameter, inches	21
thickness, inches	3
Crank pins and crank shaft journals, diameter, inches	10½
length, inches	13½
Crank webs, width and thickness, inches	12 and 6¼
Thrust shaft, diameter, inches	9¾
collars, number	9
diameter and thickness, inches	15½ and 1¾
actual thrust surface, square inches	575.04
couplings, diameter and thickness, inches	29 and 3
bolts in each flange, number and diameter	6 of 2⅜
Length of thrust bearing, feet and inches	5– 5¼
Intermediate shaft, diameter, inches	9¾
Propeller shaft, diameter, inches	10½
Thickness of composition shaft casing at bearings, inch	¾
elsewhere, inch	½
Length of stern bearing, feet	4
inboard bearing, feet	3

PROPELLERS.

On the *Manning*, there is one solid, manganese bronze propeller, which is secured in place by a feather key, $2\frac{1}{4} \times 1\frac{3}{8}$ inches, and a steel nut screwed on and kept from backing off by a key driven through the end of the shaft. The propeller of the

McCulloch is of the built-up type, with four blades of manganese bronze secured by bronze studs to a cast steel hub.

The physical requirements for the manganese bronze in both wheels were a tensile strength of not less than 55,000 pounds per square inch, an elastic limit of at least 18,000 pounds, and an elongation of not less than 18 per centum in a length of 2 inches.

	Manning.	*McCulloch.*
Number of blades	4	4
Diameter of propeller, feet and inches	11– 0	11– 0
Pitch, true, feet and inches	12– 4	12– 6
Greatest width of blade, feet and inches	2– 6	2– 9½
Length of hub, inches	23	24
Helicoidal area, square feet	40	43·
Disc area, square feet	95.03	95.03
Ratio, pitch to diameter	1.12	1.14
disc area to area of immersed midship section	.31	.26
Immersion of center of propeller at mean draught, feet and inches,	6– 6	7– 9

MAIN CONDENSER.

The condensers are of cast iron in three sections bolted together, and form a part of the framing of the main engine. Openings are provided for connections to the main and auxiliary exhaust pipes, supplementary feed, evaporator, soda tank and boiling-out nozzle. No auxiliary condenser is provided, the intention being to use the main condenser as an auxiliary, and for this purpose a connection is made from the auxiliary feed pump to the bottom of the air pump channel way.

	Manning.	*McCulloch.*
Length over all, feet and inches	16–5¼	16–4
Width of shell, inside, feet and inches	2–0½	2–0½
Thicknesss of shell, inch	1	1
Length of tubes between tube sheets, feet and inches	14–5	14–5
Number of tubes	1,253	1,217
Outside diameter of tubes, inch	⅝	⅝
Thickness of tubes, B.W.G. No	18	18
Condensing surface, square feet	2,962.8	2,877.6
per horse power, square feet	1.21	1.13

PUMPING OUTFIT.

Each vessel is fitted throughout, with the exception of the circulating pumps, with pumps of the Blake system. The air

pumps are of the double, vertical, single-acting type. The pumps are secured to the main condenser and are connected by beams pivoted at the center, which receive their motion from the cross-heads on the pump and piston rods by means of links. The steam cylinders are 9, and the air cylinders, 20 inches in diameter, the stroke being 12 inches.

The circulating pumps are of the independent centrifugal type. The pump suctions are 12, and the delivery, 10 inches in diameter. Each vessel is fitted with two main injection valves, one at the bottom and the other at the side. An automatic-closing bilge injection valve is also fitted.

. The main and auxiliary feed pumps are of the vertical, duplex, Navy pattern with composition water ends. The steam cylinders are 8, and water cylinders, 5 inches in diameter, the stroke being 5 inches.

Each vessel is fitted with a powerful fire pump which is also of the vertical duplex type, having steam cylinders 14, and water cylinders, 8½ inches in diameter, and a stroke of 12 inches.

In addition to the above, the pumping system comprises a distiller circulating pump, which can also be used for fire purposes, a combined fresh and salt water pump, a bilge pump, an air pressure pump for the fresh water supply tank and an automatic pump in connection with the steam heating system.

DISTILLING APPARATUS.

Each vessel is fitted with an evaporator and a distiller capable of producing 3,500 gallons of potable water in twenty-four hours. There is an independent connection between the evaporator and the main condenser to provide additional feed water direct.

ELECTRIC LIGHT.

Both vessels are lighted throughout by electric lights, and each is provided with a search light of 25-ampere capacity, having a ground glass reflector 12 inches in diameter. The plant on the *Manning* consists of one 10-kilowatt General Electric Co.'s dynamo, producing 125 amperes at 80 volts. The dynamo is operated by a direct-connected, vertical, double engine, designed

for a working pressure of 80 pounds. The cylinders are 6½ inches in diameter, the stroke being 5 inches. There are 131 16-candle power lamps in the various compartments of the vessel. The plant on the *McCulloch* is only of 7 kilowatts' capacity, as there are but 100 fixed lights. It is of the same general description as the plant on the *Manning*, except that the dynamo is operated by a single engine and the voltage will be 110.

OTHER AUXILIARIES.

In addition to the above auxiliaries, there are on each vessel a steam steering engine, steam wind-all, See's hydro-pneumatic ash ejector, and a workshop engine which operates a lathe, shaper, drill press and drill grinder.

FORCED DRAFT.

The forced draft is of the closed fire room system, air being supplied by two 54-inch fans, one on each side of the fire room. Each blower is driven by a two-cylinder, direct-acting engine, the diameter of the cylinders being 5, and the stroke, 4 inches.

BOILERS.

There are four single-ended Scotch boilers, all 11.5 feet in diameter, arranged in pairs in one water tight compartment, with a single athwartship fire room between them. The shell of each boiler is made from only two plates, thus dispensing with the central circumferential seam, so usual with this type of boiler. The longitudinal seams are double butt-strapped and treble-riveted, while the two end circumferential seams are lapped and double-riveted. Each boiler has two Fox's corrugated steel furnaces. The material used in the construction of the boilers is of the best mild open-hearth steel, except the boiler tubes, which are of charcoal iron. Each boiler is fitted with one main and one auxiliary feed check and stop valves, sentinel valve, two 3-inch safety valves, a bottom and a surface blow valve, circulating apparatus in connection with the internal feed pipe, and a steam gauge. The zinc for boiler protection is suspended from the stays in wrought iron baskets, with their sides perforated and

bottoms solid. This prevents the disintegrated zinc from dropping to the bottom of the boiler and choking the blow valves.

Air locks are fitted in the passageway between engine and fire rooms, and in each fire room for use while hoisting ashes through the ventilators.

The following are some of the principal data of the *Manning's* boilers. They will apply to the boilers of the *McCulloch*, except in the number of tubes, which is slightly less, and, consequently, in the total heating surface.

Designed steam pressure, pounds	160
Length over all, feet	10
Diameter, outside, feet and inches	11- 6
Number of furnaces	2
Diameter of furnaces, outside, feet and inches	3-10
inside, feet and inches	3- 6
Length of grate, feet	6
Outside diameter of tubes, inches	$2\frac{1}{2}$
Length of tubes between sheets, feet and inches	7- 3
Spacing of tubes horizontally and vertically, inches	$3\frac{3}{4}$ and $3\frac{1}{2}$
Number of ordinary tubes (No. 10 B.W.G.)	178
stay tubes (No. 6 B.W.G.)	46
Number of combustion chambers	2
Depth of combustion chambers, inches	$23\frac{1}{2}$ and $24\frac{1}{2}$
Width of combustion chambers, feet and inches	4-10
Thickness of shell plates, inches	$1\frac{1}{16}$
heads and tube sheets, inch	$\frac{3}{4}$
combustion chamber plates, inch	$\frac{1}{2}$ and $\frac{5}{8}$
furnaces, inch	$\frac{9}{16}$
Diameter of rivets in longitudinal and circumferential seams, inches	$1\frac{1}{8}$
Pitch of screw stays, inches	7×7
Diameter of screw stays, inches	$1\frac{3}{16}$
Number and diameter of through braces above tubes, inches	16 of $2\frac{1}{4}$
braces to back tube sheets, inches	2 of 2
around lower manhole, inches	1 of 2 and 2 of $1\frac{3}{4}$
Tube heating surface, one boiler, square feet	1,080.5
Plate heating surface, square feet	215 8
Total heating surface, square feet	1,296.3
Grate surface, square feet	42
Area through tubes, square feet	5.94
over bridge walls (two), square feet	6.4
through uptake, square feet	8.23
Volume of furnaces and combustion chambers above grates, cubic feet	160.8
Steam room, water six inches above tubes, cubic feet	235.52

Water surface, water six inches above tubes, square feet	99.94
Diameter of smoke pipe (inside), feet and inches	6–3
Area of smoke pipe, square feet	30.68
Height of smoke pipe above grates, feet	54
Diameter of main and auxiliary stop valves, inches	5 and 4
Totals for four main boilers:	
Total heating surface, square feet	5,185.2
Grate surface, square feet	168
Area through tubes, square feet	23.76
over bridge walls, square feet	25.6
through uptakes, square feet	32.92
of water surface, square feet	399.76
Volume of steam room, cubic feet	942.08
furnaces and combustion chambers above grates, cubic feet,	643.2
Ratios:	
Total H.S. to G.S.	30.86 to 1
Area through tubes to G.S.	.14 to 1
of water surface to G.S.	2.38 to 1
Steam room per sq. ft. G.S., cubic feet	5.60
Volume of combustion chambers and furnaces above grates and bridge walls per sq. ft. G.S., cubic feet	3.83

THE TRIALS.

The trial of the *McCulloch* took place at sea off Cape Henlopen, at the mouth of Delaware Bay, on April 29. The vessel left Cramp's shipyard at 7 A. M., arriving at the course at 2 P. M. Forced draft was then applied and the vessel run for a period of four hours, during which time a known distance of twelve nautical miles between two sea buoys was traversed four times without slowing the engine at the turns. The weather was fine, there being no breeze, and the sea was practically smooth. Pocahontas coal was used during the forced draft trial. Steam at the maximum pressure was easily maintained without great effort on the part of the firemen. The main engine and the auxiliaries worked very satisfactorily in every particular, all bearings running cool without resorting to the water service. The vibrations of the hull were no more than are usual in a vessel of this class. As neither stores nor outfit were on board during the trial, and the bunkers were not full, the mean draught was 20 inches less than it will be under cruising conditions. This will account for the comparatively fast speed obtained, when taking the designed displacement into consideration.

The trial of the *Manning* took place at sea off Boston, Mass., on July 15. The vessel left the wharf at 7 A. M. and proceeded down the harbor. Compasses were adjusted in President's roads, and the trial commenced. After proceeding but a few miles, a dense fog bank was encountered, which caused an alteration of the course. The four hours' forced draft trial consisted of a number of runs between the whistling buoy off the Graves and Boston light ship, during which time the engine was not slowed. The average speed maintained during these runs was 16.68, and the maximum for one run, 16.94 knots. At the conclusion of the forced draft trial, the vessel was run under full speed with all four boilers under natural draft, and developed a speed of 15.97 knots. Under natural draft, and with but two boilers in use, the vessel made 12.21 knots for one hour. The mean draught during the trial was 12 feet, which is within 3 inches of the designed draught. During the trial, the performance of the steam machinery was very satisfactory. The steam pressure in the boilers did not vary more than five pounds from the maximum at any time, and the revolutions for the fifteen minute periods varied at the greatest by only six per minute. No water was used on any of the bearings, thus demonstrating the high quality of workmanship used in the construction of the engine and its appurtenances.

DATA OF TRIALS.

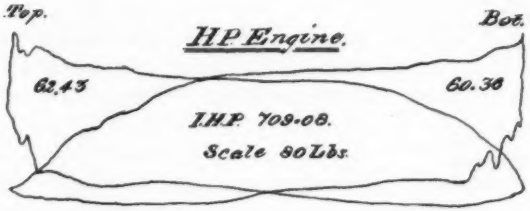
	Manning.	*McCulloch.*
Draught, mean, for trial, feet and inches	12–0	12–4
Displacement at mean draught on trial, tons	950	1,060
Area of immersed midship section, square feet	293	308
Wetted surface, square feet	6,754	7,388
Average speed, in knots	16.68	17.23
Slip, per cent	12.57	7.98
Revolutions of main engine per minute	156.23	151.8
Piston speed, in feet per minute	781.1	759.0
Steam pressure at boilers, per gauge, pounds per sq. in	159.3	161.3
engine, per gauge, pounds per sq. in	146	150
in first receiver, pounds per square inch	58	61
second receiver, pounds per square inch	13	14
Vacuum in condenser, inches of mercury	24.5	24.5
Opening of throttle	wide.	wide.
Steam cut-off in fraction of stroke from beginning, H.P	.617	.672

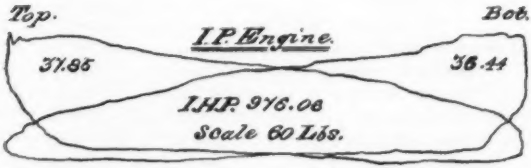
	Manning.	*McCulloch.*
Steam cut-off in fraction of stroke from beginning, I.P.	.701	.714
L.P.	.680	.719
Double strokes of air pump per minute	35	41
feed pump per minute	25	26
Revolutions of circulating pump per minute	158	165
Temperatures in degrees Fahrenheit, engine room	88	92
injection	52	51
discharge	120	155
feed	118	125
fire room	92	90
Average air pressure in fire room, inches of water	1.7	1.6
Revolutions of blowers per minute	650	775
Mean pressures in cylinders, H.P.	50.23	56.23
I.P.	35.03	35.82
L.P.	15.81	15.86
aggregate equivalent, reduced to L.P.	40.9	39.18
I.H.P., H.P. cylinder	564.2	639.5
I.P. cylinder	911.4	784.3
L.P. cylinder	929.7	815.5
total for main engine	2,405.4	2,239.3
air pump, estimated	8.6	9.3
circulating pump, estimated	8.2	10.1
feed pump, estimated	7.8	8.3
blowers, estimated	61.3	52.4
other auxiliaries, estimated	14.3	12.4
total for all auxiliaries	100.2	92.5
machinery in operation	2,505.6	2,331.8
Indicated thrust, main engine, pounds	47,349	42,303
per sq. ft. developed blade area, pounds	1,183.7	983.8
per square inch of thrust surface, pounds	83.6	72.0
Cubic feet swept per minute by L.P. piston per I.H.P.	5.60	5.84
Square feet of cooling surface per I.H.P.	1.16	1.24
heating surface per I.H.P.	2.07	2.23
I.H.P. per square foot of G.S. (all machinery in operation),	14.9	13.8
Maximum performance (one run):		
Speed in knots	16.94	17.34
Average revolutions, main engine	158.4	155.3
I.H.P. for main engine (average)	2,518.93	2,482.3
auxiliaries, estimated	112.0	106.0
Total I.H.P., main engine and auxiliaries	2,630.93	2,598.3
Air pressure in fire room, inches of water	2.00	1.9

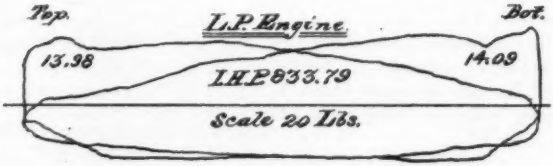
U. S. Revenue Steamer.

"MANNING."

July 15th 1897 ——— 11.35 A.M.
Steam Pressure ——— 145 Lbs.
Revolutions per. min. ——— 158.4.
Vacuum ——— 24.5 Ins.



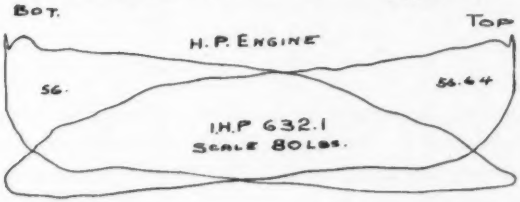


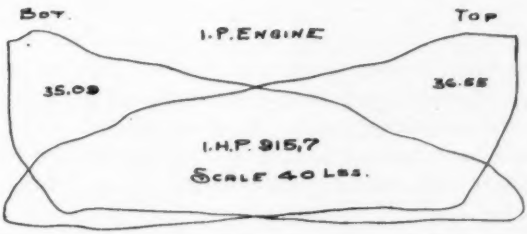


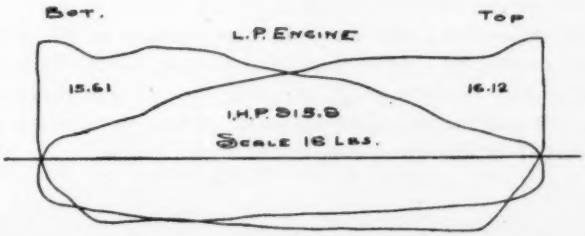
U. S. Revenue Steamer

Mc Culloch

April 29th 1897 ..... 3.45 P.M.
Steam pres. at Engine ..... 149 Lbs.
Revolutions per. min. 154
Vacuum ..... 24.5 Ins.







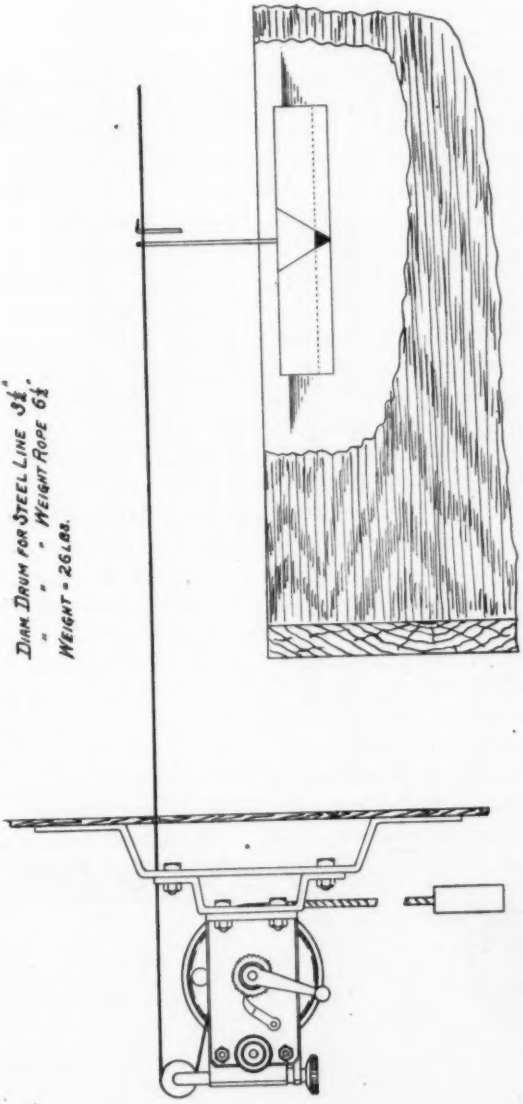
METHOD OF MEASURING THE SAG AND LINING UP SHAFTING.

By Passed Assistant Engineer W. Strother Smith,
U. S. Navy.

The following apparatus for measuring the sag of a fine steel line was devised by Mr. J. A. Williams, connected with the Newport News Shipbuilding and Dry Dock Company, and the results were put in use in erecting targets and laying out for boring the struts and stern tubes, and in aligning the shafting for the battleships *Kearsarge* and *Kentucky*.

Against the wall of a long lumber shed was built a water trough, about eight inches wide, six inches deep, and two hundred and eighty feet long, the bottom of the trough being made as nearly level as could be. A V-shaped tin float was made as shown in the cut and weighted at the bottom of the V. The reel for the steel wire was made with fine ball bearings for the drum and guide pulley, and was erected at one end of the trough, (see cut.) On one end of the wire drum, a window sash cord was secured and partly wound around it. To the free end of this cord a weight was attached, and thus the tension of the wire kept constant.

At every ten feet along the length of the line, horizontal battens were erected, and were adjusted by means of the pointer on the float to the same distance above the level of the water in the trough; from these battens the sag of the line was measured. The work of measuring was done in the early morning after a calm and still night, when the vibration and motion of the building was reduced to a minimum, and every precaution was taken to ensure accuracy. After measuring the sag for the line at a length of two hundred and eighty feet, the line was shortened by ten feet and the sag again measured, and so on until the sag for a thirty-foot line was taken.


Diam. Drum for Steel Line 3/4".
" " " Weight Rope 6 1/2".
Weight = 26 lbs.

10	20	30	40	50	60	70	80	90	100	110	120	130	140
15/64	15/32	11/16	7/8	1 1/16	1 7/32	1 23/64	1 31/64	1 15/32	1 23/64	1 47/64	1 25/32	1 13/16	1 53/64
15/64	29/64	41/64	53/64	63/64	1 9/64	1 17/64	1 3/8	1 15/32	1 17/32	1 19/32	1 5/8	1 41/64	
15/64	7/16	5/8	51/64	61/64	1 3/32	1 7/32	1 5/16	1 25/64	1 29/64	1 1/2	1 17/32	1 17/32	
7/32	27/64	19/32	3/4	57/64	1 1/64	1 1/8	1 7/32	1 9/32	1 11/32	1 3/8	1 25/64		
7/32	13/32	37/64	47/64	55/64	63/64	1 5/64	1 5/32	1 7/32	1 17/64	1 9/32	1 13/64		
13/64	25/64	35/64	11/16	13/16	59/64	1 1/64	1 5/64	1 9/64	1 11/64	1 3/16			
3/16	23/64	1/2	41/64	49/64	55/64	15/16	1	1 1/64	1 5/64	1 3/32			
11/64	21/64	15/32	39/64	48/64	51/64	7/8	39/64	61/64	63/64				
11/64	21/64	29/64	37/64	11/16	49/64	53/64	7/8	29/32	29/32				
5/32	19/64	27/64	17/32	5/8	45/64	3/4	25/32	13/16					
5/32	9/32	13/32	1/2	37/64	21/32	45/64	23/32	23/32					
5/32	9/32	25/64	15/32	35/64	39/64	41/64	21/32						
5/32	17/64	23/64	7/16	1/2	35/64	37/64	19/32						
9/64	1/4	21/64	13/32	29/64	31/64	1/2							
1/8	15/64	5/16	3/8	27/64	29/64	29/64							
1/8	7/32	9/32	11/32	3/8	25/64								
7/64	13/64	1/4	19/64	21/64	11/32								
3/32	11/64	7/32	1/4	9/32									
5/64	9/64	5/16	7/32	7/32									
5/64	1/8	11/64	3/16										
1/16	7/64	9/64	9/64										
1/16	3/32	7/64											
3/64	5/64	5/64											
1/32	3/64												
1/32	1/32												
1/64													

Sag of Steel Line.

In the accompanying table, the sag for each ten feet from one end to the middle of the line is given. The first horizontal row of figures gives the distances, the succeeding rows, the sag in inches or parts of an inch. Although the sag on each side of the middle of the line would, naturally, with a uniform wire, be the same, still the sag was actually measured and the two sides found to agree.

The table will easily be made applicable to the whole length of the line, by repeating the figures of the sag, in regular order, from the heavy black *square*, for lengths of 280, 260, 240, &c., and from the heavy black *line*, for lengths of 270, 250, 230, &c.

The steel line used was a special manufacture of the finest piano wire, and is guaranteed to be of the same diameter by the most microscopical test for every fraction of its length, and similar wire could be obtained from the same source, in case any accident occurred to the one used in the present case.

The practical application of this line and the sag table was made in the battleship *Kearsarge* as follows.

The base line was carefully laid off and battens erected in the horizontal plane of the line. The vertical line of the hull was laid off on the center of the stern post, and by means of measuring rods and scales, a point on the outboard end of the shaft line was established. The inboard point was established by the same means on the forward bulkhead of the engine room, a measuring rod being run down through the inner bottom by means of a rivet hole left for that purpose. With these two points established, the reel was set up inboard, and the steel wire made fast at the outboard point. Targets were set up and the line then lifted until there was no sag. From this line, all points were laid off for boring, and the main thrust and spring bearings were adjusted.

ON THE ADVANCES MADE IN THE MATHEMATICAL THEORY OF NAVAL ARCHITECTURE DURING THE EXISTENCE OF THE INSTITUTION.

By Sir Edward J. Reed, K. C. B., F. R. S.

[Paper read at the International Congress of Naval Architects and Marine Engineers.]

At the first meeting of this Institution on March 1, 1860, the late Dr. Woolley, who was in the highest degree qualified for the task, read a paper on "The Present State of the Mathematical Theory of Naval Architecture," in which paper the whole ground covered by the title was well surveyed. It was possible at that time for a man like him to go hastily over the field of scientific naval architecture, for its advancement in all the generations that had gone before had not carried it beyond the grasp of an individual, or the compass of a single discourse. The Council of the Institution, in this year of great commemorations and congresses, has thought it well to impose upon me the task of presenting a brief notice of the progress made in this field during the existence of the Institution, and, as the subject is so extensive, I will spend no time on apologies for undertaking the duty cast upon me. Such a summary of actual progress can have no claim to novelty, or to any other merit than of a generous notice of the labors of others; but, however imperfect, it cannot fail to illustrate the fact that, if the Institution of Naval Architects has powerfully assisted, as I am sure it has, in advancing the theory of our profession from its state in 1860 to its present condition, then has it taken a very important part indeed in that scientific expansion which is perhaps the greatest glory of our Sovereign's reign.

The mathematical theory of naval architecture naturally separates itself into the following divisions: (1) The science which

deals with the strains to which ships are subjected at sea, and with the provision of the strength necessary to withstand them; (2) the science which regulates dimensions, forms and weights, so that vessels may float under all conditions with due displacement, draught of water and stability; and (3) the science which provides for so adapting form to fluid resistances that vessels may be propelled, either by external or by internal forces, with due economy and security.

The first of these divisions occupied no part of Dr. Woolley's paper, but I have introduced it here, because of the great importance it has assumed in these days of long and large ships. A full exposition of its principles would have to start with an investigation of all the strains to which ships are subjected, and to comprise a theoretical explanation of the manner in which these are all provided for. This investigation has not, within my knowledge, yet been made, or even attempted, in any connected or exhaustive manner. The transition from wood shipbuilding to iron, which had made some progress in 1860, has been succeeded by the abandonment of iron for steel, and nickel steel now appears likely to replace steel; while other alloys, such as bronze and aluminum, have occasionally been more or less employed. It would be a great advantage, doubtless, were a theory of strain and of strength worked out in such a form as to prescribe minimum scantlings and proper butt and joint connections for all forms of sea-going ships, and for all parts of them, adjustable by means of constants to the use of various metals of known strength and durability. But the production of such a theory, and its embodiment in appropriate formulæ, is a task reserved for the future, and one not unworthy of the labor of some of our younger men. All that has been done in this respect during the existence of our Institution is to prepare the way for such a theory, and much work of this preparatory kind has been accomplished. The Transactions of the Institution abound with records of partial investigations, calculations and experimental data.

In dealing with this particular matter I find it necessary to summarize in three or four sentences the early work done upon it. A century and a half ago, the famous French originator of

so much of our naval science, Bouguer, in his "Traité du Navire," projected estimates of the strains upon ships, of no great value in themselves, as his assumptions were very wide of the truth, as he acknowledged; but he nevertheless laid down the system of graphically representing relative displacements and weights, from point to point, along the length of the floating vessel, which is in principle what we still do for a like purpose. A few years later Euler, who was Director of the Prussian Academy of Science, produced his famous treatise on rolling and pitching, in which, although he dealt but little with statical strains, nevertheless took note for the first time of the longitudinal bending effect produced in a ship by the longitudinal pressure on the immersed part. In a later work ("Théorie Complète"), this author again dealt with the subject; but, like his predecessors, attempted no quantitative estimates of strain. Romme followed Bouguer's line of inquiry, and then Seppings, in this country, took the matter up, but advanced it little himself, his practical work upon ships, however, being referred to our Dr. Young—a man remarkable at the beginning of this century for mastery in several branches of science. The Doctor examined and reported on the subject to the Royal Society, giving quantitative results from actual ships, and taking into much fuller view than any previous writer the principal causes of straining in ships. The celebrated Dupin reviewed the work of Seppings and Young, and cast much light upon the subject.

It remained pretty much as he left it (so far as I know) until I entered upon the subject at the Admiralty in 1869, at a time when it had become of great importance, and when I enjoyed the signal advantage of having upon my staff, and available for this purpose, a naval architect who has since become well known to fame, and has distinguished himself greatly as the designer of many of the finest warships in the world—Sir William White—and with him our lamented friend Mr. W. John. The line of investigation adopted by us, which was of the most practical character that could be given to it—our calculations being founded upon the graphical representation of the buoyancy and weights, estimated in short lengths from stem to stern, of several

of H.M. ships of different types—developed results very different indeed from some of those which had hitherto been accepted, and disclosed consequences which had not at all been foreseen.* In the year 1874, Mr. John read a paper to this Institution in which he summarized this system of inquiry, which I had previously applied only to certain of H.M. ships, and extended it to vessels of the Mercantile Marine. This paper was followed by another, in 1877, from the pen of the same able investigator, who, I may say, after receiving the highest available training in H.M. School of Naval Architecture, and at the Admiralty, had become one of the leading members of the staff of Lloyd's Register Office under our eminent and valued friend Mr. Martell. In his first paper Mr. John displayed, in a remarkable manner, the tendency that then existed—when, as now, larger and still larger ships were continually coming into vogue—to bring the materials composing them under continually greater tensile strains per square inch as the ships increased in size, as illustrated in the following table, deduced from calculations made on a series of vessels that were at the time fairly representative of the Mercantile Marine of this country:

Tonnage of vessel.	Maximum tension on the upper works in tons per square inch.
100	1.67
200	2.36
300	3.09
400	3.55
500	3.95
600	3.72
700	4.57
800	4.59
900	4.8
1,000	5.19
1,500	5.34
2,000	5.9
2,500	7.08
3,000	8.09

* These investigations were published *in extenso* in the Transactions of the Royal Society in 1871, and were pretty fully reproduced in "Naval Science," Vols. 1 and 2. The summary of them given at the commencement of Mr. John's paper of 1874, about to be mentioned, though brief and imperfect, absolves me from the necessity of repeating here any part of these investigations or of their results.

All these vessels approximated to the proportions of eight breadths in length and eleven depths in length, their scantlings representing as fairly as possible those generally adopted at the time for first class vessels. After also estimating the strength of some vessels above 3,000 tons, the author was induced to believe that their maximum tension ranged in many cases between 8 and 9 tons per square inch. "In a vessel over 400 feet long, whose strength I investigated quite recently, I found the maximum tension 8.85 tons. These forces," he said "are not sufficient in themselves to cause rupture in a vessel well built of good materials; but they may be sufficient to cause very considerable straining, which, if not attended to in time, must weaken the vessel to the point of danger." As ships at that time were mostly built of iron, of which the tensile strain did not, as a rule, exceed, or much exceed, 20 tons per square inch, it is obvious that the factor of safety was not more than $2\frac{1}{2}$, and, therefore, much below that assured to structures on land. The late Sir William Fairbairn—no mean authority of his day—in his work on "Iron Shipbuilding," advised that the strain brought upon the material should not exceed one-fourth or one-fifth of its ultimate strength, on account of the fact that the changes of strain are not merely effective as regards their *amount*, but also as regards their *direction*. His final conclusion was that, with iron, a strain of 5 tons per square inch on the material, acting alternately in opposite directions, would at least injure, if it did not ultimately fracture, the material after a great number of alterations. Professor Rankine also considered that the strain should not exceed one-fifth of the ultimate strength.

The first paper of Mr. John's had nothing of the alarmist character about it, erring, if at all, the other way; for, after discussing in detail a ship, the tension upon whose deck stringer plates rose to more than 8 tons in some conditions of lading and some states of the sea, he refused to pronounce her as unsafe, or dangerously weak for the trade she was in, or even to say that "she is a weak ship as ships go," alleging that she had for years been doing her work in an unexceptional manner, and acknowledging that we did not often hear of vessels breaking in two afloat. He confessed, however, that "we are trespassing on the

margin of surplus strength to an extent which creates in my mind an uncomfortable feeling." In his later paper he had to acknowledge that several cases of vessels breaking asunder at sea had come under his notice, and he investigated very fully the case of a comparatively small vessel (210 feet by 25 feet) which broke in two from the excessive amount of compressive strain cast upon her upper deck at sea. This was a vessel of light draught, and the sagging strains when she was stretched across the hollow of a wave of her own length were by far the greatest strains to which she was exposed. It was a case analogous to, but much worse than, that of the *Victoria* and *Albert* given in my own Royal Society paper. I will only add in this connection that Mr. John very properly drew attention to the great difference that undoubtedly exists between the case of land structures exposed daily to the fatigue of enduring the maximum weights and strains, and the case of a seagoing ship which has only to endure them occasionally. The point is so vital to a just appreciation of the matter as he left it—and I do not think this aspect of it has been much advanced since—that I add the following paragraph from his second paper:

"In engineering structures of iron, five tons per square inch would be considered quite as high, and in many cases higher, than it would be prudent to go with the ordinary working load; but this would be for an everyday load, and there is a marked difference between such cases and the exceptional strains of a ship. For ordinary working loads and fair weather strains, perhaps no engineering structures in existence have larger margins of surplus strength than iron ships, and this helps them the better to bear exceptional strains. There are, of course, limits which should govern the margin of safety against exceptional strains, but it is a difficult matter to deal with them, and they can only be arrived at by very careful attention to the teachings of experience and an accurate investigation of the facts bearing on the subject as they arise."

It would be leaving the general question of our recent progress in respect of strain and strength in a very imperfect condition, if I failed to take passing note of three remarkable papers submitted to the Institution in the years 1882, 1890 and 1894,

respectively, by three naval architects, two of whom have unhappily been taken from us. I refer to the papers "On the Transverse Strains of Iron Merchant Vessels," by the late Professor Jenkins and the late Mr. T. C. Read; "The Distribution of Shearing Stress Over the Transverse Section of a Ship," by the former; and a third by the late Mr. Read, and another accomplished member of Mr. Martell's staff at Lloyd's Registry Office, Mr. Stanbury, exhibiting certain detailed verifications and limitations of well-known formulæ of stress and strain; and I gladly avail myself of this, the first, opportunity which my paper affords of expressing in general terms the deep obligation which this Institution owes, in my opinion, both to Mr. Martell and his predecessors at Lloyd's Register Office, for the help afforded us, from our very first session until now, in every department of our work.

The first of these papers presented the first close mathematical investigation of the distribution of transverse strains with which I am acquainted, but it was confined to the case of a vessel in dock, without cargo, kept upright by breast shores only, and supported by the keel alone. The results demonstrated the need of transverse strength in the engine and boiler spaces of a steamship, "where the localized weights of the engines and boilers, and the want of support from the deck above, due to the small number of beams, increase the strains at the middle line and the bilge." To the second paper I will presently devote a paragraph. The third paper, by Messrs. Read and Stanbury, is an extremely valuable one, as it exhibits in much detail the degree of correspondence which they found to exist between the well-known stress formulæ,

$$\frac{p}{y} = \frac{M}{I} = \frac{E}{\rho} \qquad \text{and} \qquad \frac{d^2y}{dx^2} = \frac{M}{EI}*$$

* p = the stress at any particular point;
y = the distance of the point from the neutral axis;
M = the bending moment of the impressed forces;
I = the moment of inertia of the section of the beam through the point, and perpendicular to the neutral axis, about a line through the neutral axis, at right angles to the forces bending the beam;
E = the modulus of elasticity of the material of which the beam is composed; and
ρ = the radius of curvature of the neutral axis of the beam under the loads.

first in the case of certain rolled Z-frames and channel bars, and of certain riveted steel and iron frames with riveted reverse frames; and afterwards in the case of actual ships. The general result reached was that "there appears to be good reason for supposing that the actual deflections of a vessel do not differ greatly from those which are obtained by calculation." This result should be borne in mind, notwithstanding the admissions which I am bound to make in the next paragraph.

I must now devote a few words to the paper of Professor Jenkins of 1890. This paper was of much value in helping us to assign quantitative values to the "shearing stresses" exerted at sea upon various parts of a ship's section, and thus indicating both the causes of, and the remedies for, much of the weakness which has been observed to exist in parts of vessels, chiefly at and above the turn of the bilge. The investigation was in this respect founded upon the fact (long before referred to by Rankine in his work on shipbuilding) that the shearing stress is not uniform over a section such as that of a ship. No exception can be taken to the work of Professor Jenkins in this particular. But the Professor's paper points to the necessity of making perfectly clear what he seemed not altogether to apprehend*, viz., that all the investigations concerning bending moments and inferred strains initiated by myself, with the aid of Sir William White and Mr. John, were perfectly well known by us (and we thought by everyone) to be but approximations to actual moments and strains, and subject to modifications whenever, in the progress of science, it might become possible (*a*) to select for each ship the wave or waves best adapted to her form from point to point, as well as to her length; (*b*) to so analyze

* In Professor Captain Kriloff's admirable paper of last year, on "A New Theory of the Pitching Motion of Ships on Waves," referring to my investigations, it was asked, "Is the approximation so obtained sufficient?" in other words, "Is it possible to neglect the *inertia* of the ship's pitching motion?" If the gallant Professor had consulted my Royal Society paper he would have found this matter discussed on p. 445 and onward. It was distinctly pointed out that increased strains would result from the vertical movements of the ship and the sea respectively. He is perfectly correct in his own views upon the matter; but he failed to observe that they had been anticipated.

the structure of waves as to determine precisely how much upward pressure they exert upon a ship in transit across them at each step of the transit; (*c*) to determine by these and other means the precise variations in the effective forces of gravity, if I may so speak, of both ship and water at the crests and hollows of the waves selected; and, generally, to introduce all those refinements, and those quantitative corrections, to which our somewhat rough process of assuming for our ship momentary statical equilibrium upon wave crests, and in wave hollows, was of course liable. I do not hesitate to say that all these obvious qualifications of our results were perfectly present to the minds of Sir William White, Mr. John, and myself, when we worked upon the subject at the Admiralty, and when, almost as soon as they were obtained, our results were communicated in the form of lectures to the students of the Royal School of Naval Architecture, so many of whom have done honor to their training. It is most necessary to have the approximate nature of such calculations clearly understood. Subject to that, the question of shearing stresses was not only treated in my Royal Society paper and lectures more than twenty years before, but it was even then also carried by Messrs. White and John much beyond the bounds of such publication as they were then able to give to them. I believe, nevertheless, that Professor Jenkins was the first to bring into scientific and quantitative form for the service of naval designers the question of the due distribution of strength throughout the section to meet the real distribution of the shearing stresses.

I have made this first division of my paper of some length, because I believe the whole subject, as understood and worked out in practice in so far as this country is concerned at least, to be the product of the period covered by the title of my paper—the fruit, in fact, of that tree which was so fortunately planted when this Institution was founded. It has nevertheless to be repeated that we are very far from possessing a comprehensive theory of strains and strengths, such as might enable the designer at once to apportion the latter to the former in all cases. This is acknowledged by the very highest authorities. At a confér-

ence of naval architects held a few weeks ago in London, I drew attention to the remarkable nearness that exists between the strengths of ships and the estimated strains at sea to which they are subjected, pointing out that shipbuilding practice presents us with no such large "factors of safety" as we all require in bridges and other land constructions. Sir William White and other speakers truly pointed out that practical experience has made it certain that no such large factors of safety are really requisite in ships. But it seems equally certain that no one can say at present what the factor should be, even as regards longitudinal strength, and its determination is one of the results to which we may confidently look forward.

In coming next to the regulation of dimensions, forms and weights of vessels in order that they may float with the necessary draught, displacement and stability, we enter upon a division of the subject which itself naturally separates into two sub-divisions, viz: calculations of immersion with the vessel at rest, or presumed to be so; and calculations of movements under the influence of disturbing forces, other than those of propulsion.

The calculation of the volume of a ship's immersion has undergone some development since the Institution commenced its labors. The field, however, is a somewhat limited one, and no revolutionary or large changes have been, or can be, effected. In our first paper (1860), Dr. Woolley presented us with a novel and elegant method of his own, for estimating the cubical contents of a solid body bounded on one side by a surface of varying curvature. I doubt if that method has ever been sufficiently appreciated and put into operation, outside of the Admiralty, although it greatly facilitates the calculation of both the displacement and center of gravity, and might be used with like advantage for calculating the internal capacity of a ship. In 1865, a lamented former secretary of the Institution, who was also Principal of the Royal School of Naval Architecture more than once, the late C. W. Merrifield, presented us with a series of papers or notes upon this section of the geometry of our subject, bearing testimony to the value of Dr. Woolley's contribution to

it as being "one of the most interesting and useful additions to our rules of calculation which have been given during the present century." He claimed for it a degree of accuracy considerably in advance of any measurements which the shipbuilder can obtain from either his drawings or his frames; and, acting in concert with the Doctor, extended the principle to a triple integral. Just as Simpson's first rule applies to the cubic parabola, and Dr. Woolley's to the cubic paraboloid, Merrifield's rule applies to the ternary cubic. The late Mr. H. J. Purkiss (whom we lost by a deplorable accident in the very flowering of his great mathematical talent), taking note of the work of Woolley and Merrifield, sought out a general formula for a multiple integral, of which the Simpson, Woolley and Merrifield rules would be but particular cases, and obtained an expression which proved equivalent to Simpson's first rule when the variable was but 1, to Woolley's rule when the number of variables was 2, and to Merrifield's when the number was 3. It clearly exhibited the connection between those three cases, and showed that their resemblance was not accidental. The other papers of Merrifield were "On Successive Integration, Arranged so as to Yield Ordinates for a Scale of Areas," and on "The Measurement of Curved Surfaces by means of Ordinates." These papers gave brilliant expression to the ability with which Mr. Merrifield brought his great mathematical powers to bear upon problems which are of profound interest to our profession, and not without value in other professions. Mechanical aids to the calculation of areas have so much reduced the actual work and time required as to diminish greatly the relative advantages and disadvantages of the respective geometrical methods of estimating areas and volumes. I refrain from discussing the estimation of weights in a ship design, as it is an arithmetical rather than a mathematical matter.

The calculations of stability have undergone great improvement in this country since the commencement of our work as an Institution. In his paper of 1860, Dr. Woolley sketched in clear outline the work of Dupin, giving the characteristics and relationships of the various loci of the centers of buoyancy, the

centers of gravity of the water line planes cutting off equal displacements, &c. In order to acquire a just conception of the progress made since, we must carefully bear in mind that we have had no new elements and no new principles to deal with since 1860; all that could be done was to present the old materials in new aspects or in new combinations, having due regard to the improvement of the practical calculations; for in every ship, or ship-like floating body, detailed calculations, or equivalent mechanical experiments, must be made to suit the particular case presented, if they are to be more than approximate. It is only in theoretical cases, such as those of bodies of symmetrical form, or in mere approximations, that exact calculations can be dispensed with.

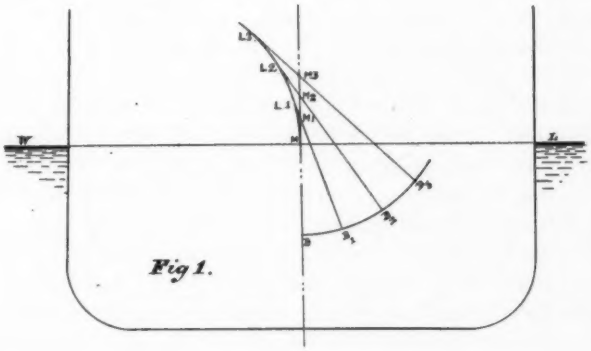


Fig 1.

I should like, before advancing with this section of my paper, to say that there are some difficulties of definition and nomenclature in this matter that it is necessary to take note of. I will mention them very briefly. In this country it was long understood that, for an ordinary ship, floating in the ordinary manner, there was but one "metacenter," viz: that due to a slight inclination from the upright. It was necessarily situated in the vertical center line of the ship. Of late years some persons have fallen into the habit of speaking of a large number of other points as metacenters, while the French also designate by the same word

a large number of other points, theirs being quite different from ours. Let me illustrate this, for confusion in respect of elementary matters is a very bad form of confusion. The simple diagram, Fig. 1, illustrates both the error we commit, and the difference between French and English practice. In this figure, M is the point which we all agree to call the metacenter, and is a metacenter proper. B is the corresponding center of buoyancy in the upright position; B_1, B_2 and B_3 are other centers of buoyancy at successively greater angles of inclination. The lines $B_1 L_1$, $B_2 L_2$, $B_3 L_3$ are radii of curvature of the curve of buoyancy at the points B_1, B_2 and B_3 respectively. M_1, M_2 and M_3 are the points in which these radii cut the original vertical axis of the ship BM. Now the French call the points M_1, M_2 and M_3 (and all other such points) metacenters, but connect each such point with the angle of inclination to which it corresponds, so that no misunderstanding need arise. In this country some writers call the points L_1, L_2, L_3, metacenters; but they clearly are not so,* and cannot be so called without confusion in dealing with ship calculations. They are, no doubt, obtained, like the metacenter itself, by the intersection of two closely adjacent lines through which the buoyancy acts upwards; but in dealing with ship calculations it is well to keep the original upright axis of the ship in mind, and to call nothing a metacenter that is not situated in it. The curve through the points L_1, L_2, L_3, is really the locus of the points in which a series of these closely adjacent lines of upward pressure intersect, that locus being, as known to most of you, the *evolute* of the curve of buoyancy. This evolute is sometimes spoken of as the "metacentric evolute." In my writings on the subject I have, for the sake of clearness, called all such points as L_1, L_2 and L_3 "pro-metacenters," as they serve, for some limited purposes, at larger inclinations, the same ends as metacenters serve in the upright position; and the curve

* "This term is, we think, open to the very serious objection that it is not a metacenter—*i. e.*, limiting position of the ship's center of gravity, in the true sense of the word, as separating stable from unstable or neutral equilibrium. It is very likely to be misunderstood by the unlearned or the sciolist, and seems really to have misled."—Dr. Woolley in "Naval Science," Vol. III, page 441.

ML_3 I call, accordingly, the "curve of pro-metacenters." Such points as M_1, M_2, and M_3 (the French "metacenters at given angles") have been sometimes called among us "shifting metacenters," but this designation is not wholly free from objection. In strictness there can be but one metacenter for one draught of water; but these points have, at any rate, the merit of lying, all of them, in the vertical axis of the ship, and reasonable care in the use of the words "shifting metacenter" may avoid any very great confusion. I fear it is too late to abolish the use of Bouguer's word "metacentric" (*métacentrique*) as a designation for the evolute of the curve of buoyancy, or to get rid of its other appellations, "metacentric evolute" and "metacentric curve," although the fact of the metacenter being a point upon this curve is the only justification—and a very poor one—that I can find for these designations.* Against one thing, however, I have protested, and do protest, viz: the calling of this curve a "curve of metacenters," as some writers have done. It is no curve of metacenters, properly so called, and that designation must be reserved for a curve constructed to represent the relative positions of true metacenters at different draughts of water, which is an altogether different matter.

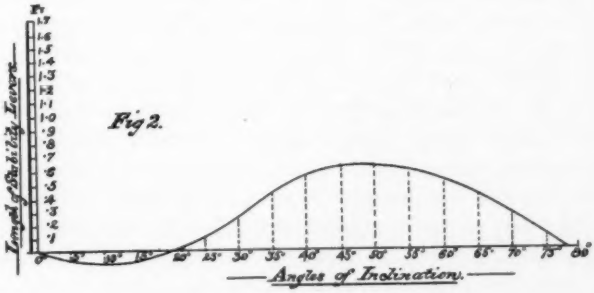


Fig 2.

* I am, of course, well aware that Bouguer headed his fifth chapter "On More Extended Investigations in the Metacenters and the Curve Line which these Points Form when the Ship is Inclined," and that he calls the "metacentric evolute" the *métacentrique*. But Bouguer himself fell into error in connection with this matter, and it is not desirable either to create, or to perpetuate so confusing a nomenclature.

Very serious objection has been taken by some scientific writers, notably by Professor Osborne Reynolds, to the confusing use which undoubtedly exists of the word "stability" itself. It has been pointed out that the word "stability" is often employed as the equivalent for the length of the righting lever, known generally as *GZ*, or for this length multiplied by the weight of the ship. Professor Reynolds, at the British Association a few years ago, said "In recent literature on naval architecture the term stability occurs over and over again in the sense of righting moment, and this under circumstances where the context shows the meaning to be incompatible with any meaning that can be given to the word, for stability must refer to some position in which the ship is stable"; and he went on to develop this objection at some length, particularly pointing out, what is perfectly true, viz: that the righting moment exerted by the buoyancy at considerable angles of inclination is often found to be effective, not in restoring the body to an upright position, but merely in restoring it to some other less inclined position, in which it will remain if left free to do so. The truth of this is well known to most of those present, but it may be as well to give the curve of stability of an actual ship illustrating the case, Fig. 2. This ship has a negative metacentric height of 6 inches, and she lolls over 20 degrees before she begins to acquire an opposing moment. From 20 degrees to nearly 80 degrees she has a righting moment of precisely the same kind as any ordinary ship; but this moment only returns her *toward* and not *to*, the upright position. Again, when we speak of righting levers and righting moments (which are but conditional measures of rotating forces) as identities with or equivalents of "stability," we reach the anomalous position of having, even in a ship of very great stability in the popular sense of the term, no stability at all when she is upright, or, as in the case just illustrated, none at all when she lies free and at rest at 20 degrees of inclination. There is nothing in all this which presents any difficulty to the expert naval architect; but, as I have lately had frequent occasion to take note of very incongruous views and conflicting expressions of opinion arising from these troublesome anomalies,

and have observed judges, counsel, mercantile marine officers, and even members of a Parliamentary committee, greatly puzzled by them, it seems to me most necessary to put people on their guard against them. I would even suggest whether we might not, in view of the growing importance of the subject, appoint an International Committee for arranging, and, so far as practicable, settling, both improved definitions and an improved nomenclature for this much cultivated branch of naval science.

The progress made in the development of the doctrines and of the practice of stability since 1860 has been so extensive that, although I endeavored to condense my work, this one subject covered nearly 400 pages in a volume which I devoted to it ten years ago. In educational establishments, in the practice of the Admiralty and of the mercantile shipbuilding yards, on board ship, and in shipping institutions, the study of stability in its most recent forms has exceeded all that could have been anticipated. Three successive incidents contributed so strongly to this result that, although I was personally connected with two of them, I feel constrained to notice them.

I refer, first, to the investigations which led to the production of the now familiar "Curve of Stability." In this country, certainly, the practical need for detailed measurements of stability at large angles had not arisen in 1860, all ships being more or less high-sided, and, therefore, stable enough at comparatively large angles, even in the days when all ships were sailing ships.* But when we came to consider low-sided sailing ships the matter assumed a wholly different aspect; and when in 1867 or 1868 proposals to cut down certain of H.M. ships to low freeboard sailing ships were made, it became my duty as Chief Constructor of the Navy, to look seriously and responsibly into them. I accordingly determined to have the stability of a particular ship (which had been named for this treatment) calculated

* "In fact, so far as our knowledge extends, there seems good reason to believe that no consideration was given to the range of a ship's stability, and that, until four years ago, no calculation had been made of the stability of a ship with the upper deck partially immersed."—Messrs. White and John "On the Calculation of the Stability of Ships," &c., in Trans. N. A., 1871.

at 5 degrees inclination, and at successive intervals of 5 degrees each, until the stability disappeared; and this constitutes the first of the three incidents mentioned. Mr. (now Sir Nathaniel) Barnaby was desired to see these calculations carried out, and to submit to me the results. Mr. John was the member of the Admiralty staff chosen by Mr. Barnaby to make the calculations in detail, and when Mr. John had obtained the quantitative results it occurred to him to embody them in a diagram, with angles of inclination for abscissæ, and the lengths of the righting levers (*GZ's*) set up as ordinates at their corresponding angles.* This diagram was brought to me with the other results, and in April, 1868, I submitted to this Institution a paper "On the Stability of Monitors Under Canvas," in which I gave the results, illustrating them with the said diagram, which subsequently formed Plate VI of Vol. IX of our Transactions. The diagram was afterwards spoken of as a "curve of stability," and thus the first "curve of stability" (as the term has since come to be understood among us) came to be constructed and placed before this Institution and the world. In their joint paper of 1871, Sir William White and the late Mr. John said of my paper of 1868: "It showed conclusively that instability would occur in such (low freeboard) vessels at a very moderate angle of inclination, and illustrated the contrast, as regards stability and safety, existing between rigged ships with high freeboard and

* Mr. John afterwards mentioned to me that he thought it so natural to record the results in a diagram, just as we record so many other measurements varying from point to point (for example, in calculating the volume of displacement by the ordinary rules, having calculated the areas of certain bounding sections, we make these areas the ordinates of another curve) that he constructed the diagram quite incidentally, and without even intending to submit it; but afterwards considered that I might find it convenient for reference, and consequently sent it forward, together with the figures I had called for, and of which it was a mere reflection. In fact, at a discussion in this Institution in 1884, Mr. John himself referred to these particular calculations, explained the original method by which he effected the measurement of the righting levers at successive large angles of inclination, proceeding beyond the immersion of the edge of the upper deck, and added: "Having obtained them, and wanting to find out where the stability really vanished, it was the most natural thing in the world to form a curve out of the spots, and that became the now well-known curve of stability."

those with low freeboard. . . . This paper did not succeed, however, in impressing members of the profession with the necessity for more complete calculations of stability, and the subject remained in comparative obscurity until the loss of the *Captain* forced it into painful prominence."

This loss of the *Captain* was the second incident to which I referred above, and it will now be admitted that Messrs. White and John were true prophets when they added: "It does not seem too much to say that this great calamity will mark an epoch in the science of naval architecture." The paper of those gentlemen was one of the early and great contributions to the science of the new era; and another, and very valuable one, was made at the same meeting by Sir Nathaniel Barnaby on the relative influence of beam and freeboard on curves of stability, and both the results of his investigations, and the illustrative diagrams attending them, presented a most impressive view of the dangers of low freeboard when associated with a considerable spread of canvas.

It unhappily required a further incident, and another calamity, to open men's eyes to the very opposite danger, viz: that of ships capsizing at light draught. In 1883 the *Daphne* capsized on the Clyde during launching, and I was sent down by the Government to inquire and report upon the accident. The inquiry developed several facts which showed how much need there was for large extensions of stability calculations. It proved that ships of modern type are sometimes characterized when floating light by very abnormal deficiencies of stability in inclined positions. The *Daphne* herself possessed not only small stability, but a slow growth of it with increase of inclination. No curve of stability at the launching draught had at that time been calculated for any ship. Sufficient initial stability had been always regarded in ordinary ships as a guarantee of sufficient stability at all angles. Even the highest of our authorities at home had assumed this to be the case. All this proved, however, to be quite erroneous.

It has therefore happened, since we commenced our work as an Institution, that novel professional exigencies have laid upon

us the necessity of guarding equally against the dangers both of *deficient* and of *excessive* immersion, and have consequently greatly enlarged the boundaries up to the limits of which the designer has to work. It will be seen that naval architects have promptly cultivated the enlarged field.

One consequence of the earlier incidents above mentioned was to excite the educational authorities to special exertions. At the Royal School of Naval Architecture—of which the high officers of the Admiralty were in chief control, Sir Nathaniel Barnaby first, and his successor in office, Sir William White, caused the students to apply themselves to the work of carrying out elaborate calculations, alike for the purpose of applying received methods to the estimation of the stability of specific ships or designs, and for the further purpose of testing, or giving effect to, novel methods. A principal of that school, the late Mr. Merrifield, devoted himself to the production of methods of approximation for the ready estimation of stability, taking, as a fundamental assumption, the assumed identity of the curve of buoyancy with a conic. The labor of finding the true position of the inclined water line was got over by constructing from the ordinary water lines a mean section of the ship, and making out a scale of displacement for this section at various immersions. The radius of curvature was found by finding the moment of inertia of the water line plane of the given inclination, and dividing it by the volume of displacement, as usual. Professor Rankine improved upon this by assuming that the curve of buoyancy is not a conic, but the involute of the involute of a circle, the "metacentric evolute" being thus assumed to be an involute of a circle. Dr. Woolley, again, improved upon Rankine's system, while employing the same assumption as he to the extent of assuming that the portion of the involute of a circle lying between any two successive radii of curvature practically corresponds with the corresponding portion of the evolute itself. He employed a succession of such evolutes, which were calculated in their *ensemble* to coincide fairly with the metacentric evolute. The method was not founded on the principle of finding the radius of curvature in any extreme position, but on that

of obtaining a succession of radii at given finite angles. Although it was found that, applying the system to a prismatic body, and taking the angular intervals to be 5°, the error was only about two per cent., Dr. Woolley nevertheless considered all these approximate systems, although fascinating as geometrical problems, so inferior to exact methods, that he readily abandoned his own as well as the others in favor of Mr. Reech's more perfect system, of which I will presently make mention.

In speaking briefly of Admiralty practice in this matter, subsequent to 1860, I must do Mr. Barnes, one of our most capable professional Vice Presidents, the justice of saying that more than one of his great contributions to the advancement of our stability work was made without the stimulus of any precedent calamity. In 1861 he presented us with a new method of calculating the statical and dynamical stabilities, which was so clear, so sound and so practical, that it displaced at the Admiralty all other methods. Sir William White, ten years afterwards, spoke of it as affording the first means which we possessed of readily effecting the necessary calculations. In 1864, Mr. Barnes—who has always brought a rare combination of sound mathematics and strong practical sense to bear upon such questions—gave us another stability paper, in which he proposed the application of the longitudinal metacenter to the calculation of changes in a ship's trim. He also was the first person, I believe, to devise and publish the "metacentric diagram," of which I will presently speak.

The later developments of Admiralty work have been most remarkable. In his paper of 1871 Sir William White, with Mr. John, gave us a most valuable account of such modifications and extensions of Mr. Barnes' method as modern conditions had made desirable, and of the detailed work of carrying them out; and proceeded, with a courage which their experience justified, to apply to the illustrious Dupin one or two of those corrections which the theorist generously allows the practical man the exquisite pleasure of discovering. A little later (in 1878) Sir William White gave us a most instructive discourse upon the geometry of the "Metacentric Diagram" introduced by Mr.

Barnes, and I have been gratified, on referring back to this paper, to find how skilfully Sir William White avoided that confusion of language into which a less expert investigator might easily have fallen. For here we have a case of those "metacentric curves" which are wholly different from the others to which I have previously referred as bearing precisely the same

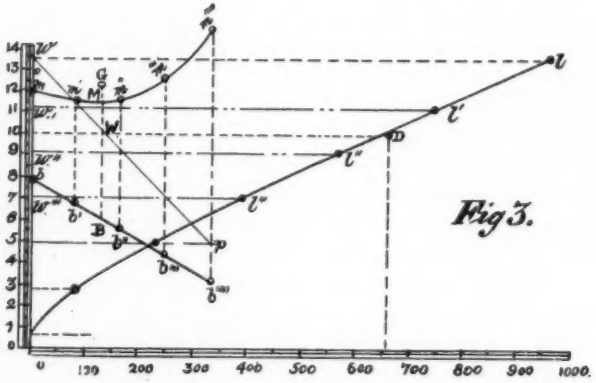


Fig 3.

designation. While those previous curves, although called metacentric curves, are nothing more, as we saw, than curves of pro-metacenters, here, in Sir William White's paper, we have curves of actual metacenters to deal with. Such metacentric diagrams have to do with different draughts of water, and are employed to show the variations in the metacentric height at those different draughts. I much wish that time allowed me to do justice to this paper, and to its applications to ships both of war and commerce. The manner in which theoretical views and actual calculations for ships are combined for the improvement of our work presents in Sir William's paper an example of the best possible professional work. All that I can allow myself to do, for the sake of clearness, is to give the following brief description of a "Metacentric Diagram" and how it is formed.* A series of horizontal lines $w' l'$, $w'' l''$, &c. (Fig. 3), are drawn

* From "Stability of Ships," p. 82.

at heights representing on some convenient scale the various mean draughts of water at which the positions of the metacenters and centers of buoyancy have been calculated. An oblique line, *op*, is drawn across these horizontal water lines, inclined to them at an angle of 45°; and, from the points at which this line intersects the respective water lines, are drawn vertical lines, upon which are set off, on the same scale as before, the distances down of the centers of buoyancy, *b*, *b'*, *b''*, &c., below the corresponding water lines, and from these centers of buoyancy are set up the corresponding metacenters, *m*, *m'*, *m''*, &c. A fair curve passed through all the metacenters so obtained, and another passed through all the centers of buoyancy, will respectively be a curve or locus of metacenters, and a curve or locus of centers of buoyancy. It is often found convenient to have the scale of displacement represented on the same diagram. For this purpose, a vertical line is drawn through the intersection of the oblique line before mentioned with the water line corresponding to the load draught of the ship. From this vertical line are set off, on any convenient scale of tons, in a horizontal direction, the calculated displacements at the draughts represented by the water lines before used; a fair curve passed through all the points thus obtained is the curve of displacement, as shown in Fig. 3. From this complete diagram the position of the metacenter can be obtained for any given displacement, draught of water, or position of center of buoyancy within the given limits; and in like manner, for any given value of either of the latter, the other corresponding positions can be obtained.

It will be seen from this description that this metacentric diagram deals only with variations of draughts of water, whereas the curve of pro-metacenters deals only with changes of inclination.

Another highly competent and distinguished naval architect, Dr. Elgar, one of our Vice Presidents, introduced a still more ingenious mode of exhibiting stability elements in a diagram. This was communicated to the Royal Society, and possesses the advantage of giving in one diagram the variations of stability for variations both of draught of water and of angle of inclination. These cross curves of stability, as they are called, are formed

from curves of stability (of the ordinary kind) made for the light, load, and two or three intermediate draughts of water. The measures of stability at the respective draughts, at one given angle, are made the horizontal ordinates of a vertical curve which may be described as a vertical curve of stability at that particular inclination. A similar vertical curve is drawn for each other angle of inclination. The *ensemble* of these vertical curves is the complete diagram. By employing these curves in their turn, as furnishing measures of stability at different draughts and inclinations, the number of ordinary curves of stability may obviously be increased to any desired extent.

While the Admiralty stability work has been extending, beyond what I have shown, not a few private shipbuilding firms have pursued a similar course, developing in some instances new methods of investigation suited to the special requirements of mercantile ships. I can but cite an example or two. Messrs. Denny Bros., of Dumbarton, followed up the cross curve system of Dr. Elgar, or possibly worked it out independently for themselves, with the aid of a group of scientific assistants, making large and ingenious use of the mechanical integrator for the purpose. They employed numerous draughts of water, and found it perferable, under their system, to calculate the cross curves first, and take from them the usual curves of stability, for the given draughts of water. The late Mr. Jenkins likewise worked with advantage at this subject, and facilitated, by a particular investigation, the determination of the exact depths of immersion at which the righting moment attains its maximum and minimum values.

Another example of a like kind is furnished by Mr. Inglis, of Pointhouse Shipyard, Glasgow, who applied the metacentric diagram to the varying conditions of merchant vessels in a novel and valuable manner. Mr. Inglis was good enough to favor me, for use in my book on Stability, with the diagram, Fig. 4, which exhibits the system he pursues. The horizontal scales at the bottom of the figure are two in number, the one being a scale of feet for showing the height above the floor and ceiling available for the cargo, the zero being at the top of keel, and the

cargo space commencing somewhat more than two feet above it; the other being a scale, also in feet, of draught of water, and the stowage of cargo, on the assumption, that the cargo is of such a specific gravity as to bring the ship (when filled with it) to

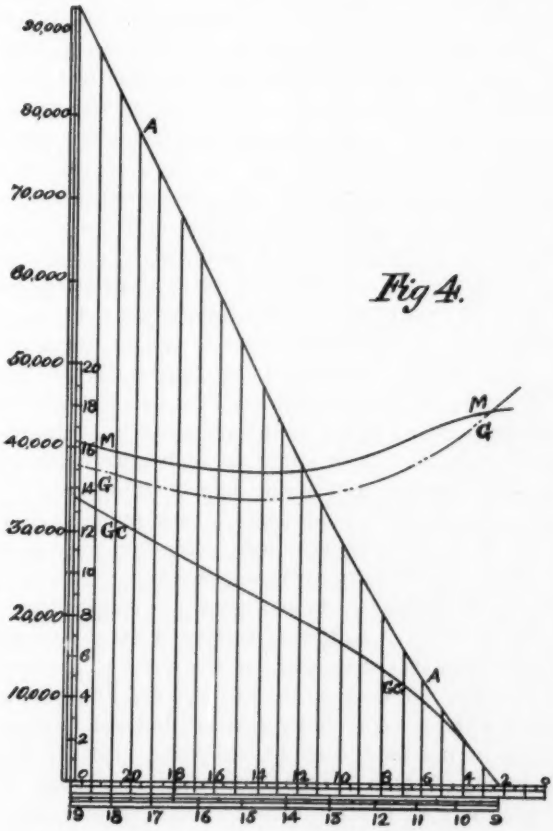


Fig 4.

her designed load draught, and is poured in, so to speak, in such manner as to keep its surface always level. The upright scales are also two in number, the one being a scale of cargo capacity

in cubic feet, from which may be read off the quantity of the homogeneous cargo on board at any time by means of the "curve of capacity," to be presently mentioned; and the other being a scale of feet, set off above the top of the keel, serving as a scale of heights for centers of gravity and metacenters. The curve *AA* is the "curve of capacity" before mentioned; by taking any point upon this curve, and projecting it horizontally upon the vertical scale of capacity, the number of cubic feet on board (from which the number of tons which it weighs may be inferred, there being allowed in this instance 58.5 cubic feet per ton of deadweight, or a specific gravity of .615) can at once be seen; while projecting the same point vertically downwards upon the horizontal scales, the corresponding depth of cargo in hold, and the corresponding draught of water of the vessel can be read off. The curve marked *GC* exhibits from point to point the heights of the center of gravity of the homogeneous cargo, these heights being read off from the vertical scale of feet at the side of the figure; the curve *GG* represents the heights of the common center of gravity of both the ship and the cargo, and the curve *MM* represents the heights of the metacenters (within the requisite limits), both of these latter sets of heights being read off from the same vertical scale at the side of the figure. A comparison of the curves *GG* and *MM*, at any point, exhibits the measure of metacentric stability which the ship possesses, with the corresponding quantity of homogeneous cargo of the given specific gravity on board. In arranging this diagram, and making the assumptions as to specific gravity of cargo and stowage on which it rests, it is presumed that the worst case which need arise is provided for, because the cargo is the lightest possible compatible with its being homogeneous, and yet bringing the ship down to her load draught, observing that its assumed specific gravity (.615) is less than one-half that of coal. If any part of the cargo be heavier than the homogeneous cargo here considered, it may be inferred that this heavier part may be placed low, so as to bring down the center of gravity and add to the stability.

In many other private shipbuilding firms similar uses have

from time to time been made of recent developments of the theory of stability, Messrs. J. & G. Thomson, of Glasgow, and Mr. J. H. Biles, their technical adviser, standing eminent among them, both on account of the completeness of the work done, and of the liberality with which they have allowed the publication of the results. Mr. Martell, at Lloyd's, has innumerable operations for testing the stability of merchant steamers carried out, and many of them made public with the enlightened sanction of Lloyd's Committee.

Turning our attention for a few moments to the labors of non-British professional men, I may be permitted to remark that, while recognizing, I hope fully, the great anticipatory labors of Bouguer, Dupin and others, and in no way seeking to claim for our Institution any credit on account of French progress—for if credit there be it must be brought to us from abroad, and there may be none due—it is nevertheless true that since the establishment of this Institution, *i. e.*, since 1860, there has actually been much work done in France in the way of applying geometrical principles, to the actual calculations of ship stability. In 1863, Mr. G. Dargnies, a former pupil of the French Naval School, and, at the time mentioned, naval architect to the *Messageries Impériales*, made stability calculations for angles of 10°, 20°, 30° and 40°, and for several draughts of water intermediate between the light and load draughts. His process was essentially French. By calculating the several radii of curvature of the curve of buoyancy approximately, and laying down by means of these radii, and by a tentative process the "metacentric" (or evolute of the curve of buoyancy) he dispensed with the calculation of the centers of buoyancy. A further interesting part of the work of Mr. Dargnies consisted of means for verifying the values obtained for the metacentric radii at the various inclinations and displacements. These were obtained by the use of two sets of curves; one, corresponding to a constant displacement, having for abscissæ the angles of inclination; while the other was for a constant inclination with draughts of water for abscissæ, the ordinates in both cases consisting of the corresponding metacentric radii. These curves indicated the general forms and trans-

formations of the evolutes for the region comprised (light to load draught), the second of the curves enabling one to draw immediately the evolute for any draught within that region.

Mr. Reech,* early in 1864, having had the calculations of Mr. Dargnies submitted to him by the author, saw reason to suppose that they could be improved upon, and suggested a system of operation of more convenience, and determining more exactly both the curves of buoyancy and the metacentric evolutes of a vessel. His first improvement upon the paper of Mr. Dargnies was a repetition of a method included in his revised course on the Stability of Floating Bodies given at the Paris Naval School.

Mr. Reech went on to give another, and, as is certain, a better method of determining the metacentric evolutes of a vessel, because it set the inquiry free from the necessity of dealing with a single prescribed draught of water, and gave results in a form available for such variable draughts of water as it might be necessary to deal with. His method rests upon the fact that if we consider only inclinations round a longitudinal axis, and therefore planes of flotation perpendicular to the vertical transverse plane of the ship, any plane whatever will be fully determined by the angle of inclination θ which it makes with the original horizontal plane of flotation, and by the volume V which it cuts off. All the quantities dependent upon the volume cut off by any such plane are functions of the two independent variables, θ and V only. Nothing can be either more sound or more elegant than the manner in which the method is mathematically developed in the original *Memoire* of Mr. Reech.† The late Dr. Woolley, writing to me in 1884, said, "Reech's method is so simple, and founded on so well-known a property, that it seems wonderful that it never occurred to anyone before. . . . I am convinced that if ever the present system of calculating stability in this country be superseded, it will be by Reech's, or some other founded on it and equivalent to it." It was

*A former most able and distinguished Directeur de l'Ecole d'Application du Génie Maritime.

†The only English translation of this known to me is that published at pp. 256–263 of my "Stability of Ships" (Charles Griffin & Co.).

promptly adopted in France, and in 1870 Mr. Risbec—a well-known cultivator of this field of science—prepared a Calculation Form for its application, stating that the new method had made it practicable to carry out all the calculations of a ship's stability (with the assistance of tables of squares and cubes) as easily as calculations of displacements were carried out. I regret that the scheme of this paper does not admit of my giving here even a sketch of his methods.

It is not possible to leave wholly unnoticed the exhaustive treatment of statical stability and of its calculations worked out by Mr. Daymard, who has done us the honor of so frequently attending our meetings. Mr. Daymard has stated that it was while pursuing certain investigations of his father-in-law, the late Mr. de Ferranty (who himself labored with much success at the simplification of calculations of stability extended to large angles of inclination) that he conceived the idea of joining the extremities of the arms of righting levers (corresponding to like angles of inclination, but to different draughts of water), by continuous lines, starting on the temporary assumption of the center of gravity being identical with the center of buoyancy. The curves thus drawn—identical in principle, as will be seen, with Dr. Elgar's cross curves of stability—he called *pantocarène isoclines*, and he saw, as Dr. Elgar saw, that he could obtain from them, with exactitude, and for all possible cases, the usual curves of stability. Having obtained the means of determining the two extremities of each *pantocarène*, and of calculating directly, and in a mathematical manner, as many intermediate points as he wished, he prepared a sample table of calculations by means of which he could, "in a comparatively short time (about 40 hours) arrive at the complete representation of these curves for a ship, at intervals of 10°, from 0° to 180°, and for all draughts of water, and consequently at the entire solution of the problem of the stability of a ship." It is needless in this case to enter into further particulars, as the system was completely described in all necessary detail by Mr. Daymard himself in our 25th Volume (1884).

The limits of this paper do not admit of my doing full justice,

or anything like full justice, in respect of statical stability, to even our French friends alone, and still less to the valuable labors of numerous other foreign investigators. It would require more time, and probably more skill, than I have at my disposal, even to apportion the effective progress made in the studies of stability and stability calculations to the respective countries who have shared in the production of it, and much more to apportion it to the respective investigators in each country. To do either would be to perform the double work of distributing awards of merit, first, in respect of the geometrical aspects of the subject; and secondly, in respect of the accuracy, facility, and economy (of time) which the various improvements in actual calculations have brought about. I ought to say, however, to prevent possible misapprehension, that, bearing in mind the respective bents of the French and British minds in dealing with a subject of this nature—the latter looking mainly to the final result to be effected by such calculations, and the former, although looking also to that result, nevertheless allowing itself frequent and splendid excursions into ideal geometrical regions —there seems to me no good reason to doubt that both France and Britain have been well served.

It has to be acknowledged, of course, that in all the calculations for statical stability the assumptions involved, if not wholly imaginary, are so in a large degree. For example, the usually assumed statical position of a ship inclined through a given angle in still water, subject to a considerable righting force, is admittedly of that character. Nothing but an external applied force could bring her into such a position, and any such applied force, with some possible exceptions, would certainly alter her immersion. I mention the matter, not because I regard it as impairing the results of our stability calculations (for the imagination is a faculty of supreme necessity to the pursuers of science everywhere, and in mathematical work that which is most purely imaginary is often the most true); but because it is a matter which has to be borne in mind in approaching the dynamical aspect of stability, and points to the desirability of keeping continually in view the fact that all the ultimate problems of sta-

bility are necessarily dynamical problems. A ship at absolute rest in still water, could one exist, with no disturbing force whatever acting upon it—no air of heaven even breathing on it—would, of course, exert or elicit absolutely no stability in the technical sense of the word. To bring stability, or the exercise of a righting force into play, disturbance is obviously necessary. In an investigation of Mr. M. E. Guyou, of the Navy of France, entitled "Théorie Nouvelle de la Stabilité de l'Equilibre des Corps Flottans" (which falls within the period under review), the author lays it down, with some insistence, that the problem of stability is necessarily and purely a dynamical problem. He says we cannot speak of an actual floating body being in equilibrium in any other sense than that, being made to undergo a small disturbance, it will, after a series of oscillations, necessarily return to its primary position. There is nothing, of course, really novel in this view—nothing novel, I mean, to those who have mastered the principles of the subject; but we have also to consider the nautical and outer world. There is very much novelty, and very much beauty, too, in the manner in which Mr. Guyou pursues his inquiries, dealing mainly with a body afloat in a vessel containing water, and discussing the movements and conditions of both the fluid and the floating body, and their relations to each other, on perfectly sound dynamical principles. I need hardly remind members of the Institution that Mr. Bertin, in his valuable "Notes on Waves and Rolling," passes by an easy transition from the statical to the dynamical operation of a ship's righting forces; while Messrs. Risbec and Duhil de Benazé treated the subject from the point of view that all the work done by the oscillations of a ship proceeds solely from the vertical displacements of the center of gravity and the center of buoyancy. I may add that long before either of the above gentlemen entered the field, and before even our own lamented vice president, Canon Moseley, brought forward his famous exposition of dynamical stability—which he fondly supposed to be perfectly novel—the question of dynamical treatment received recognition and consideration from Mr. Moreau, a former professor of the French *Ecole Royale du Génie Maritime.*

Professor Moreau in 1830 published at Brest a work in which the dynamical view of the question was clearly set forth. It was, however, only small oscillations that Moreau considered, and he employed his results only for obtaining maximum and minimum values of the height of the center of gravity. It was no great anticipation, therefore, of Moseley's much larger and farther-reaching investigations, and, such as it was, was unknown to him; for, in his Royal Society paper of 1850, in which he first made his system known, Canon Moseley said: "I cannot find that the question has before been considered in this point of view, but only in that which determined whether any given position be one of stable, unstable, or mixed equilibrium, or which determines what pressure is necessary to detain the body at any given inclination from such a position."

The calculation of dynamical stability for still water conditions presents no difficulty. Leaving aside for the moment all consideration of external disturbing forces, and dealing only with the smooth water case, no room for difference of opinion exists. It practically resolves itself into a question of the amount of work done in inclining a ship from one given position to another, and this can be ascertained by multiplying the weight of the ship into the vertical distance through which the centers of gravity and buoyancy have separated during the inclination. If again, we take the ordinary curve of statical stability (*GZ's*) for the ship, and set off upon it the angles before and after inclination, the *area* of the curve between the ordinates at those points will give the same thing, or rather be proportional to it (as the weight must, of course, enter in as a multiplier); for the area of the curve between those ordinates will represent the sum of the infinitesimal items of work done from point to point. By calculating all such areas, and making them ordinates of a new curve, a curve of dynamical stability is obtained.

It is when the effects of winds and waves are brought in that the difficulties commence, and it cannot, I think, be said that the problem has yet received its complete and final solution. Even the mode of accounting for the inclining force of the wind upon sails, by graphically setting apart portions of the curve of

stability for the wind's consumption, so to speak, has not always been similarly dealt with even by competent investigators. When wave action is likewise brought into account, the differences between them have been increased. In fact, one ingenious and singularly clear headed naval architect took exception to the parceling out of the curve of stability into divisions respectively appropriated to the effects of the wind and of the waves. He much preferred to take them both into account by assuming the ship under sail to be rolling in the worst waves she is likely to encounter, and then struck by a squall at that part of her roll at which the force of the squall would be most dangerous.

It must be acknowledged that this Institution has been most fortunate in having had unfolded, under its auspices, in a remarkable manner, the mathematical theory of a ship's rolling among waves. So early as at its second meeting the late Mr. Froude, in an extempore address, afterwards brought into written form, expounded to us his novel and beautiful theory of rolling, which has formed the basis of all that has been done since in this country on this subject. That address excited the greatest possible attention, and, although received with some doubt and distrust at first, even by our most mathematical colleagues, has taken its permanent and lofty place in the science of our profession. It is quite true that Bernouilli, a century before, had written a most remarkable "Mémoire," and obtained for it the prize of the French Royal Academy of Sciences, founding his investigation upon the assumption that the oscillations of waves will prevail over those of the ship, so that the "periods" of both will come to be identical, the *amplitude* of the rolling only being dependent upon the ship's natural time of oscillation. He initiated the idea—so much resorted to since—of assimilating the motion of the ship in waves to that of a pendulum whose natural oscillation was disturbed by an external force recurring periodically. He applied the formula for the pendulum to the case of the ship, and in some degree anticipated the point which Mr. Froude so much and so properly insisted upon, viz: the danger that may result from an approximate equality between the natural time of oscillation of the ship and the wave period.

But the paper of Froude was a wholly novel and noble piece of scientific work, and elicited from the late Canon Moseley, the only Englishman of that time who had worked publicly at dynamical stability, his highest approval, as showing "that a great harvest of valuable results is to be reaped from the mathematical discussion of the more profound problems of shipbuilding science."

Mr. Froude's paper of 1861 was followed in 1862 by a most remarkable contribution concerning it from a gentleman recently deceased, my old friend and colleague at school and at the Admiralty, Mr. J. B. C. Crossland—a man second to none whom I have known in the clearness and power of his mind when applied to scientific objects; and yet so reluctant to accept publicity in any form that I had the greatest difficulty in inducing him to write his paper, and only succeeded in doing so by exercising official authority. Mr. Crossland's paper investigated the effects of stability upon a body afloat in water to which movements were imparted vertically, horizontally and obliquely; and, in point of fact, confirmed Mr. Froude's principal views by wholly independent processes, and established those views upon even more general principles than Mr. Froude himself had set forth.*

From those early days onward, throughout the whole existence of the Institution, this question has been more or less under discussion, and only last year Mr. R. E. Froude read a most valuable paper upon it. There have been many laborers in this field, and among the most distinguished of them is Mr. Emile Bertin, of whose ability and industry our Transactions display

*I would take the liberty of advising those who are interested in this branch of our science, and who have not gone back to our early Transactions, to refer to this paper of Mr. Crossland's if they desire to master the primary principles which underlie this question. The late Mr. Froude, in the debate on this paper said, "Mr. Crossland appears to me to have followed out, on an independent line of thought, and in a thoroughly common sense and sound manner, a series of steps by which the fundamental laws of dynamics may be applied directly to the elementary conditions of motion belonging to wave surfaces, and to have pursued them further, in a manner not less original and interesting, into the more intricate and difficult conditions of complete wave motion—arriving, not indeed at a complete solution of the question, but at many very instructive views respecting it."

abundant evidence. As recently as 1894, Mr. Bertin gave us a contribution upon the subject, in which, with engaging gallantry, he said that neither he nor others had thus far succeeded in greatly advancing the question of a ship's rolling upon waves that were not synchronous. At the Paris meeting of 1895, he dealt again, and with great fulness, on this aspect of the rolling question. The case of rolling on synchronous waves has, I believe we all admit, been pretty conclusively established; but rolling upon non-synchronous waves—and I am bound to say I generally find at sea that the search for any considerable series of synchronous waves is not very successful—presents us with a much wider and more debatable field. Mr. Froude, in his paper of 1896 just referred to, presents, with scientific frankness, many views different from those of Mr. Bertin, and conducts his argument with that finished skill and ample resource which make him so accomplished a successor to his illustrious father. The complexity of the problem is so great and undeniable that I feel it would be manifest folly to attempt to extract from it for your benefit even a clear statement of the situation. It is acknowledged by all that, as a rule at least, and so far as mid-ocean is concerned, the sea, if greatly disturbed, is disturbed in a confused and irregular manner. And, therefore, as Mr. Froude most truly said last year, "the *net rolling* will consist of the superposition of the system of rolling proper to the several component swells;" and, although he most ably analyzed this net rolling into its component elements, I dare not further plunge you into the many perplexities of the subject.

It is only left me to say a practical word upon this question of rolling. Recent investigation and experience have shown that the large rolling of a ship at sea may be greatly checked by the use of bilge keels, and that for smaller angles of rolling the employment of free water in suitable chambers has a similar and considerable effect. One of our much respected professional members of Council, Mr. Philip Watts, now of Elswick Shipyard, who, as long ago as 1871, wrote a masterly paper on the general question of rolling,* furnished us more recently (1885) with a

* See the Annual of the Royal School of Naval Architecture and Marine Engineering for that year.

paper on the use of water chambers, and incidentally of bilge keels, for reducing the rolling of ships, in which this subject is worked out with graphic illustrations. The use of water as ballast for merchant ships is, I fear, leading to some danger and loss, not because of any inherent defect in its use for this purpose, but because in applying it to the various objects of ballasting, trimming, and replacing fuel that has been consumed, more knowledge is required than is sometimes available, and more water ballast is needed than is sometimes arranged for. This, however, points not to defective scientific theory, but only to the desirability of extending scientific information.

I have only space to remind you that in March of last year Captain A. Kriloff, brought before us a new mathematical theory of the pitching motions of ships on waves, which elicited, as it well deserved, the highest encomiums of our most competent critics. This discourse, with others just referred to, serves to show that the mathematics of the movements of a ship at sea are still undergoing yearly development, and that this Institution in respect of this question may be proud of its past and confident of its future progress.

In his paper which forms the starting point of my observations of to-day, Dr. Woolley dealt but briefly with the question of resistence to the propulsion of ships; but in the short space devoted to it he took significant note of the unsatisfactory nature of the various theories of resistance existing at that time, refusing also to accept as in any sense conclusive the late Mr. Scott Russell's wave line theory of least resistance. That theory was amply expounded by the author of it in later papers read during the same and the following session, with all the clean-cut thought, ready humor and luminous exposition of which our departed friend was so great a master; but we have to acknowledge, I fear, that it never, in all its parts and as a complete theory, secured the assent of the great masters of naval science. It could not well have done so, even at that time, for reasons presently to appear, still less could it do so in the light that has fallen upon the subject since this Institution commenced its work. If there be any indisputable fact connected with the passage of a ship

across the water it is certainly true that, from point to point, the ship has to place itself where the water has just been. This must be admitted; but it is impossible to doubt that a very false impression of the operation performed by a moving ship was created by treating this operation (as Scott Russell treated it in his most formal communications) as a case of ordinary "excavation." Taking a particular case, he said (Trans. N. A., Vol. I), "This is an excavation of 16,200 tons of water in a minute; and this, therefore, is the measure of the minimum amount of excavation to be performed in order to clear the way of the ship." As if to remove all doubt or question, he added, "It is inevitable, and no human ingenuity can reduce it in quantity." The figures just given relate to a vessel of square section 36 feet wide by 15 feet deep; but were we to select, as we might from existing ships, the case of a vessel of about double these measurements, we should have a canal section four times greater, and the "excavation" per minute would be that of 65,000 tons of water, or 3,900,000 tons per hour, to be raised from the depth of the center of buoyancy to the surface. This extravagant conception* of the fundamental work to be executed by the propelling engines of a ship, although subject, as Mr. Scott Russell well knew and said, to qualifications, nevertheless lay at the basis of his theory of ship resistances. It is undesirable and unnecessary to pursue the subject here, as Scott Russell's proposition in no way enters into the theories of resistance which now prevail. I have only adverted to it because Dr. Woolley, far as he was from accepting it, after saying that we were then (in 1860) "as far as ever from a sound theory of resistances," went on to refer to Scott Russell's wave line theory as one which "claimed" to effectually solve the problem! It therefore has to be taken into account as

* "It is a point worth noticing here what an exceedingly small force, after all, is the resistance of a ship compared with the apparent magnitude of the phenomena involved. Scarcely anyone, I imagine, seeing, for instance, the new frigate *Shah* steaming at full speed would be inclined at first sight to credit, what is nevertheless the fact, that the whole propulsive force necessary to produce that apparently tremendous effect is only 27 tons; in fact, less than one two-hundredth part of the weight of the vessel."—*The late* W. FROUDE, F. R. S., *in his address to the Royal Institution, May, 1876.*

a theory falling within the period covered by this paper. It must not be inferred, however, from what I have said in depreciation of his theory, that Scott Russell's investigations into this branch of our science were fruitless. On the contrary, they abounded with valuable facts and suggestions, and in his first paper (1860), he drew forcible attention to a circumstance which every recent investigator must agree with, viz:—that, from Sir Isaac Newton's onward, too many views of ship resistance were inferred from experiments made with bodies situated entirely *under* the water. "A great error in inquiries of this kind has heretofore been committed," he said, "by resorting to phenomena of resistance of bodies entirely covered with water, and not only under the water, but entirely away from the surface; and by treating the results drawn from such observations as if they fairly represented the conditions of ships moving on the surface of the water." The truth of this criticism is now everywhere recognized.

It is not too much to say that in most of its essentials the theory of ship resistance has been completely changed since this Institution was founded. Were the work of "excavating" the water from the path of a ship the true measure of her resistance, it is obvious that a ship afloat on the surface with a given immersed section would experience less resistance than a ship of like section which was wholly and deeply immersed below the surface, because the ship floating at the surface would have to raise the spoil water, so to speak, a much less height than the other. But according to the now accepted theory of resistance the deeply immersed ship would be relieved from much of the resistance which is found to exist at considerable speeds, and which is due to the production at the surface (by vessels floating there, and driven there at speed) of systems of waves which can only be directly produced at the free surface. Further, the late Mr. Wm. Froude proved that at low speeds the resistance to a ship is practically due only to surface friction. It is therefore proportional to the wetted surface, and not to the transverse sectional area of the vessel; and he very properly inferred from this that the excess of resistance which is experienced at higher

speeds, and which grows with the increase of speed, is largely due to "wave making."

It has here become necessary to outline, however briefly, the means by which we have reached the present state of the theory of resistances, as distinguished from its condition in 1860, and for some time later. These means are to be traced in this country more or less specifically, and mainly, to the labors of Stokes, Lord Kelvin, Rankine and the two Froudes. It was in 1870 that the late Professor Rankine, profiting by prior investigations, presented to this Institution his version of the beautiful theory of stream lines, and stream line surfaces. These were given to us as the results of a mathematical investigation which was communicated in detail to the Royal Society. The subject had been in course of investigation by Rankine and others for several years previously, and the interim results, so to speak, had found their way, more or less, to the public; but in Rankine's paper of 1870, the results were brought up to date, and a strong impulse was thus given to the development of the modern theory of resistance. A "stream line"—one may say for the benefit of the uninitiated—is the path traced by a particle in a steady fluid current; and, therefore, when correctly depicted, a group of such lines will exhibit to the eye the motions of particles in different parts of a steady current moving round and past such an obstacle as a ship presents—the same motions resulting, of course, whether the ship moves through a fluid otherwise at rest, or the ship is at rest with the current flowing past it. A "stream line surface" is a surface which traverses a number of neighboring stream lines; and we may conceive a current to be divided by a number of such surfaces into "elementary streams." By this device the speed of the current at different points in the same elementary stream may be arrived at, because the velocity will evidently vary from point to point inversely as the area of the transverse section of the stream. The stream line surfaces passing around a body at rest are necessarily surfaces of unequal pressure, and Rankine's investigations dealt exhaustively with the relations of the unequal pressures. Of Rankine's views the late William Froude became a lucid exponent, following them up with beautiful

experimental researches, performed mainly, but not entirely, by means of models. His elucidations of these experiments, and his deductions therefrom, were so clear and so comprehensive as to present him to-day in the character of the principal founder of the modern theory of resistance.*

It will already have been seen that in order to reach this theory we had to start from very abstract considerations indeed. One of our greatest aids to clear conceptions of it is derived from something anterior even to the stream line theory as applied to water itself; for our best point of departure is the imaginary movement of a perfect fluid, which, so far as we know, and as we must indeed believe, is itself imaginary. A perfect fluid is a fluid conceived to be absolutely without friction between its parts, and devoid of all viscosity, so that no force is wasted by the movements of its particles among each other, the *vis viva* of one moving particle being transferred without diminution to another, or to others. Such a fluid would be instantaneously responsive to the pressures exerted by a body wholly and deeply immersed in it, and could offer no resistance save that due to inertia. All the time the motion of such a body is increased in velocity, differences of pressure and accelerations of motion will take place among the particles of fluid. When the disturbing body ceases to be accelerated, and moves on (as we will suppose) with a uniform velocity, a definite set of stream lines and stream surfaces will have been established; the positive and negative pressures upon the body will, by the laws of fluid motion, be precisely balanced; and the whole system of fluid particles and the body embraced by them will advance with a uniform velocity without any resistance whatever. Bring the body from the deep interior to the surface of a perfect fluid, however, and this state of things will no longer exist. The vertical reactions of the fluid from above the body will be lost; an upward movement of the parts of the fluid will take place; this upward movement will result in the formation of waves; gravitation will begin to level these waves as soon as they are created; and energy will

* See his Presidential Address to Section G, British Association, 1875, and the discourse to the Royal Institution in 1876.

consequently be lost. Hence, even were water a perfect fluid, energy would have to be expended upon a floating body to keep it moving at a uniform speed, and this energy would, of course, be the exact equivalent of the energy expended by what would be called the fluid resistance. Here we have, therefore, in the production of waves at the surface, a necessary element of resistance, which clearly will not be got rid of by the substitution of water for a perfect fluid. With this substitution, on the contrary, there will enter a second element of resistance, viz: that due to the friction and viscosity of the water, which oppose every movement of the particles, whether that movement be among the particles themselves, or past the surface of the moving body. And there is a third element of resistance which will enter at the same time, viz: that due to the energy expended upon the production of eddies by abrupt interferences with the general movements of the body and of the water, should such exist. Such is a brief account of the now received doctrine of the elements of resistance, as I understand it, which has been arrived at by the combined labors of Stokes, Rankine, the Froudes and others, but is chiefly due to the labors of the late W. Froude.

The wave-making resistance—while operating as a sternward force upon the ship, and capable in that sense of being separated in our minds from the details of wave production—nevertheless actually takes effect upon the water by producing two distinct sets of waves, of which one set travels in the line of the ship's advance, and the other diverges obliquely from it. In an eloquent passage in his address of 1894 to the Greenock Philosophical Society, Mr. R. E. Froude spoke of the visibility of the effects of each of the now recognized elements of resistance, viz: friction, eddy-making and wave genesis:—

"We may observe the effect of the skin friction resistance, in the belt of eddying water which clothes the surface of the ship from end to end, getting thicker and thicker as it approaches the stern. We may observe the effect of the eddy-making resistance, in the increase of this eddying mass of water behind the stern. And lastly, the effect of wave-making resistance shows itself plainly to every eye in the wave system which we see spreading away from

the ship. We see the effect of what I have termed the 'direct' wave making resistance in the train of large but long and gently undulating waves following in the wake of the ship, with crest lines square to the line of motion. And we see the effect of the oblique wave-making resistance, in the feathering crest which diverges from the bow, with its attendant *échelon* waves, stretching away into the distance in an oblique line as far as the eye can reach."

I am greatly tempted to descant upon this branch of the subject at some length; to speak of the quantitative division of the aggregate resistance opposed to a ship into its three elements, due to friction, wave-making, and expenditure upon eddies respectively; and to exhibit to you how many results of experience that were aforetime anomalous and inexplicable are made clear and consistent by this new and beautiful theory—one of the most fascinating that could have come to us adventurers into the science of the sea. But it is my unhappy lot to-day to be compelled to drive apace past the newly discovered territories of naval science, giving them but a distant glance at the most, and, in many cases, leaving them wholly unremarked; but I ask you, nevertheless, to believe that these territories are many and fertile, teeming with pleasure and profit for those who, at leisure, explore them. I do not think any better exposition of the modern laws of resistance can be found than that given above by Mr. R. E. Froude. Suffice it to add that the labors of a few men, conspicuous among them being officers and members of this Institution, have, since its formation, brought the laws of fluid resistance from the darkness and doubt in which even the most illustrious investigators had left them, and by the combined efforts of genius with those of painstaking experimental research—which some esteem even more highly than genius itself, but which is really the essential friend and collaborateur with genius in the disclosure of natural laws—have laid those laws open to the view, the admiration and the guidance of our profession.

And what is true of the novel and beautiful theory of resistance is equally true of the whole mathematical theory of Naval Architecture in all its parts. It is a domain in which the mind may expatiate with delight amid the charming complexities and fasci-

nating intricacies of ideal science, knowing that as we become extricated from these intricacies and complexities, and bring into view the simple laws that have occasioned them, our greatest mental qualities will find their highest satisfaction. From the same domain we gather the practical laws which so inform and regulate our professional work as to give increasing security to our sea structures, and seem to justify the hope that in the days to come no structure, however solidly founded upon the land, need surpass, either in strength or safety or beauty, the structures which the naval architect will offer to the use and admiration of the world.

In looking hastily over our transactions, with a view to this paper, I, who have been pretty closely cognizant of the work from year to year, was nevertheless overwhelmed with the magnitude and merit of the aggregate of what has been accomplished since 1860; and it has been delightful to recognize there the labors wrought by the men of France, Germany, Sweden, Russia, the United States, and some other countries. I have noted, too, with admiration, the almost total absence of jealousies and rivalries among those who, both at home and abroad, have directed trained minds to the advancement of this most attractive branch of our professional work. Debates without number almost we have had, participated in by men whose respective labors have been pursued in places apart, and not infrequently for the improvement and advantage of rival navies; and yet so neutral and so pacific is the scientific work we perform in common, that one may well declare that naval science, like the genius which develops it, is of no person, no class, no country, but is the large and splendid inheritance of all who worthily pursue it.

NOTES.

TESTS OF A DU TEMPLE—GUYOT BOILER.

On page 786 of Vol. VIII, tests were given of the earlier form of DuTemple boiler, without Guyot's modification. The following description and account of the tests of one of the modified boilers are translated from the "Mittheilungen aus dem Gebiete des Seewesens," Pola.

The modified boiler consists of a steam drum on top and two cylindrical water drums below, instead of the rectangular water drums of the original DuTemple boiler. The snake-like tubes of the earlier boiler have been replaced by slightly curved tubes, like those of the Normand boiler. Guyot's special modification, which dates back to 1893, but which was not applied to French torpedo boats until the end of 1896, consists in establishing a combustion chamber at the back of the furnace, and in forcing the gases of combustion to return between the tubes and into the uptake at the front of the boiler.

To accomplish this end, the tubes in the row next to and on each side of the fire are placed side by side without any space between them. Solid-drawn tubes with two flat sides are made for this purpose. The small exposed part of the lower side of the steam drum, not taken up by the tubes, is protected by asbestos. At the end of the furnace or grate is the combustion chamber, its sides being formed by part of the inner rows of the loosely-spaced tubes, and its back, by a wall of fire proof material, covered with a metal casing. Heated air may be admitted into this combustion chamber. The tubes in the outer row on each side of the boiler are close together, like the rows next to the fire, thus forcing the gases to return to the front between the inner tubes. Near the front of the boiler, provision is made for varying the draft by inserting movable perforated plates vertically between the tubes.

The whole boiler is clothed with a non-conducting material and a detachable metal casing.

That the above modification has increased the efficiency of the DuTemple boiler is shown by a comparison of the results of the tests given below and those given on page 786 of Vol. VIII.

The DuTemple-Guyot boiler tested was one of the six built for the French torpedo boats *Nos. 206* to *211*, inclusive, and had the following dimensions and weights.

Grate surface, 24.54, and heating surface, 1,130 square feet; ratio of H.S. to G.S., 46.05 to 1. Weight of the empty boiler, with all attachments, clothing, casings, grates, doors, uptake and smoke pipe, 12,786 pounds; weight of water, 3,197 pounds; total weight of the boiler, ready for steaming, 15,983 pounds, or 7.13 tons. In these weights, steam pipes leading from the boiler are not included.

The boiler, which was built for torpedo boat *No. 207*, was set up at the Cherbourg arsenal, in the special house fitted up for boiler tests. The tests were made on May 18 and 20, 1897, the former lasting two, and the latter, two and one-half hours. The mean results are given in the following table.

	May 18.	May 20.
Steam pressure, pounds per square inch	208.	211.
Air pressure in ash pit, inches	3.86	1.97
smoke pipe, inch	.31	.24
Coal consumed per hour, pounds	1,631.	1,058.
per square feet G.S., pounds	66 46	43.11
Water evaporated, pounds per hour	13,768.	9,634
per hour per pound of coal	8.44	9.11
Temperature in smoke pipe, degrees Fahrenheit	795.	612.

In the first test, fires were started 2 hours 50 minutes, and steam formed 1 hour 50 minutes before the beginning of the test; in the second test, the times were 2 hours 5 minutes and 1 hour 25 minutes, respectively.

MANUFACTURE OF SOLID-DRAWN STEEL TUBES.

The following description of the process of making solid-drawn steel tubes, as conducted at the Alma Tube Works of Messrs. John Russell & Co., Walsall, England, is taken from "Engineer-

ing," London. The Admiralty requirements for these tubes were given on page 814 of Volume VIII, and the similar requirements of Messrs. J. I. Thornycroft & Co., on page 127 of the February number.

The Alma Tube Works contain a modern plant for the production of steel solid-drawn tubes, and also for the manufacture of lap and butt-welded tubes. The chief development of late has been in the direction of making solid-drawn steel tubes of large diameter for Belleville boilers and very light steel tubes for cycles. The Belleville boiler tubes are made up to $4\frac{1}{2}$ inches in diameter, those for the economizers being $2\frac{3}{4}$ inches. The smaller tubes for the "express" type of water tube boiler are also made.

The manufacture of solid-drawn tubes consists essentially of two main processes, rolling and drawing, the first being a hot and the latter a cold process. The solid steel tube maker's raw material consists of round billets which come in from the steel makers. These billets are generally about 6 inches in diameter, and vary in length according to the weight or size of tube that has to be produced, the average being from 18 to 24 inches. These billets are solid, and the first operation performed upon them at the tube works is to bore an axial hole which is usually from 1 inch to $1\frac{1}{4}$ inches in diameter for Belleville tubes. This operation is carried out on a special horizontal machine, the work being done in a bath of water, and both ends being drilled at once. The drilled billet is then heated and a mandrel is forced through to enlarge the hole, which may thus be increased up to any size required, or for Belleville tubes up to about 4 inches. The operation is carried out in a powerful hydraulic press which forces the hard steel mandrel through. The hydraulic power for working this press is obtained from a central station through an accumulator working up to 1,400 pounds pressure to the square inch.

The next operation is to reduce the billet from the form of a short cylinder, which it has now assumed, to something more resembling a tube. For this purpose it is again heated in a furnace and then rolled between grooved rolls. As it is passed through

the rolls, it is at the same time forced on to a mandrel which is kept in position in the grooves of the rolls by a long bar projecting out at the back of the rolls and held by means of a rack or cross bar. As the billet is rolled, each pass it becomes longer, and, of course, each time it is forced over the mandrel it encircles the rod holding the mandrel, off which it has to be stripped for the next operation. When smaller diameters are reached, the bar cannot be made so thick as to be stiff enough to stand the thrust of the work without bending, and in that case the holding bar of the mandrel is in tenison instead of compression, and the tube has first to be threaded on to the bar each time, and is stripped in the process of rolling. There are two pairs of these rolls, a roughing and a finishing train, placed on either side of the engine which drives them. The latter is of the horizontal, compound, surface condensing, tandem type, and has circular partially rotating valves which work with a reciprocatory motion.

When the hollow billet or partially formed tube has passed through the rolling process, it is cut to length in a hot saw according to the size required, and these lengths have now to be cold drawn to the finished tube. This operation is carried out on a chain draw bench, in which a continuous chain is constantly traveling between the sides of a bed of the nature of a lathe bed. At the end, where the headstock would be in a lathe, is a hardened steel die. The end of the pipe is passed through the die, and is then seized by gripping jaws that in turn are hitched between the links of the continuous traveling chain. The tube, which contains a mandrel, is drawn through and fills the annular space between the die and the mandrel. As the hole in the die is less than the original diameter of the tube, the latter is elongated as it is drawn, and by a series of operations of this nature the tube is brought to its finished dimensions. It will be seen that the draw bench virtually repeats cold the operation carried out hot in the rolls, although the method of operating is different, and the process is one of stretching or wiredrawing rather than compressing or squeezing out, the latter naturally being more applicable to the more plastic state of the red hot metal. The mandrel is used on

both occasions to preserve the bore, and in the draw bench the hole in the die takes the place of the circular hole formed by the two half-round grooves cut circumferentially in the top and bottom rolls. In both cases, again, the opening through which the bored billet or tube passes is smaller than the work, but in the case of the draw bench motion is imparted by means of the chain, whilst the rolls carry the billet through by their own revolution.

The tubes are annealed after every pass through the dies, and after each annealing they are pickled to get rid of scale, after which they are put in a bath of oil to make them work easily through the dies. There are three large annealing furnaces which will take tubes up to 25 feet long. There are also cold saws for cropping ends in cutting to length, Ryder hammers for reducing ends to pass through dies for gripping, staving machines for thickening up the ends of tubes for screwing—the operation being performed by making the metal hot and pressing it up by hydraulic rams in dies—screwing and other machines. There are 14 chain benches, the larger ones powerful enough to take tube up to 8 inches in diameter if required. The capacity of the plant is 100,000 feet per week of small sizes up to, say, 1 inch, as well as a considerable quantity of larger diameter tube.

For very light work, such as tubes for cycle making, the gauge is further reduced, after the draw bench operations are completed, by cold rolling. This is effected by means of a pair of horizontal taper rolls placed side by side, and tapering in opposite directions. The tube is first forced over a continuous mandrel which fits the bore. In passing through, the metal is stretched by the action of the taper rolls, and by this process a tube can be reduced in gauge of metal from 9 B.W.G. to 16 B.W.G.

WATER TUBE BOILERS IN HIGH SPEED OCEAN STEAMERS.

In a paper read at the International Congress of Naval Architects and Marine Engineers, Mr. P. Sigaudy said that within the last two years, water tube boilers of the small tube type had been used so extensively and so successfully, that the time had come

to examine whether they can be applied to ocean steamers and whether the legitimate suspicion in which they were held by shipowners and marine engineers is still justified. Although remarkable results had been obtained with the water tube boilers having large tubes, yet these boilers would never bear the tests which the torpedo boat boilers undergo, in which a combustion of 80 pounds per square foot of grate has been maintained.

The author's idea was not to put on board of a large steamer a great number of torpedo boat boilers, but rather to adopt boilers constructed on the same principle and adapted to the wants of long service and great endurance at sea. Thus the diameters of the boiler chests must be larger, the tubes that now have about one inch internal diameter in the torpedo boiler will be increased to one and a half inches, and perhaps a little more. The thickness also may be much greater. Finally, the whole must be combined to make the most of the available space and weight of a large vessel.

The author's scheme for the installation of tubulous boilers on a high speed ocean steamer is intended for 23,000 H.P. in actual work; that is to say, from 26,000 H.P. to 28,000 H.P. on trials, and includes sixteen double-ended boilers of the Normand & Sigaudy type, divided into two groups of the same size and having two fire rooms for each group. The coal bunkers are situated on each side of the vessel, and the two groups of boilers can be separated by a compartment full of coal if convenient. The fore-and-aft fire rooms are outboard, and there are two smoke pipes, each having a cross section of about 123 square feet.

The dimensions and other particulars of the boilers are as follows.

Pressure, pounds per square inch	220
Number of boilers	16
furnaces to each, divided by a fire bridge	2
groups	2
Grate surface for each boiler, square feet	95
Total grate surface, square feet	1,520
Rough heating surface for each boiler, square feet	4,650
Total heating surface, square feet, about	74,400
Tubes, mean length, feet and inches	7–8

Tubes, external diameter, inches		$1\frac{7}{16}$
internal diameter, inches		$1\frac{3}{16}$
number for each boiler	1,700	
total	27,200	
Water, volume for one boiler, cubic feet	326	
total volume, cubic feet	5,216	
Steam, volume for one boiler, cubic feet	172	
total volume, cubic feet	2,750	
Thickness of material, upper chest, inches	$\frac{3}{4}$ and	$1\frac{1}{16}$
lower chests, inch	$\frac{11}{16}$ and	$\frac{1}{2}$
smoke boxes and funnels, inch		$\frac{9}{16}$
ash boxes, galvanized, inch		$\frac{9}{16}$
boiler casing, galvanized, inch		$\frac{1}{8}$
water tubes, inch		$\frac{1}{8}$

The weights of different parts for the sixteen boilers are as follows.

Boilers, complete with mountings, tons	590
Water in boilers, tons	146
Funnels, tons	100
Stokehole plates, floors, &c., tons	46
Feed pumps, tons	14
Fans and fan engines, tons	16
Feed regulators, tons	3
Spare gear (50 tons) on board, tons	20
Tools and fittings, tons	3
Total, tons	938

If the consumption of coal per I.H.P. of the engines is one and a half pounds, which is generally obtained with tricompound engines, the total combustion will be $23{,}000 \times 1.5 = 34{,}500$ pounds, or $34{,}500 \div 1{,}520 = 22.7$ pounds per square foot of grate surface, which is very small for a boiler of this type, which in destroyers supports a combustion of from three to four times as much.

The total weight of cylindrical boilers of ordinary shape, having 1,520 square feet of grate surface, is, roughly, 1,700 tons. The saving of weight is $1{,}700 - 938 = 762$ tons for the boilers only, but another reduction may be made also in the engines, when we consider that it is possible to reduce the diameter of the cylinders

on account of the very high pressure of steam which it is proposed to use with the new boilers.

It is certain that with a cylindrical boiler a pressure of over 165 pounds is obtained only with great difficulties in construction. Perhaps such a boiler is not even quite safe. With the small chests of tubulous boilers, the pressure can be increased to 300 pounds, as in H.M.S. *Pelorus*. This very high pressure gives the advantage of smaller cylinders, lighter moving weights, less distance between the axes of cylinders and, consequently, less vibration.

The comparison of weights between the two systems of boilers has been made, supposing the same combustion per square foot of grate to take place in each, but really the saving of weights could be much greater, since the only limitation to the intensity of combustion in these boilers is the durability of bricks and firebars; therefore for the same grate surface the tubulous boilers are much more powerful.

Mr. Normand has shown that, in vessels where the constant weight to be carried, as imposed by the conditions, such as cargo in high speed ocean steamers, is small in relation to displacement, any saving in weight conduces to a reduction of displacement more than four times greater, the speed and time of steaming remaining the same. Accordingly a saving of 750 tons reduces the displacement by about 3,000 tons.

It has been objected that the scale could not be removed in curved tubes. It may be so with some boilers, but with the Normand type, the author found that no difficulty whatever was experienced with a suitable chain and scraper. Even with straight tubes a chain is necessary, on account of the small diameter of the chests.

Mr. Sigaudy concluded by saying that up to this day the greatest improvements in ocean steam navigation have been successively: (1) the substitution of the screw for the paddle wheels; (2) the adoption of compound engines; (3) the triple and quadruple compounding; and that the next step will be the adoption of the water tube boiler, which will prove to be an advance of still greater importance than any of the former ones.

TWO LARGE FLOATING DOCKS.

The following data and description of the two largest docks in existence are from "Engineering," London.

The larger dock, designed and built for their own use by Messrs. Blohm & Voss, Engineers and Shipbuilders at Hamburg, Germany, was put in service in April.

The dock built by Messrs. Swan & Hunter, Wallsend, England, is for the Spanish Government at Havannah. From the time of laying the first plate to the launch of the completed dock has needed a period of six months only. The dock consists of five pontoons, which give the requisite buoyancy, and of the high side walls, which regulate the immersion of the pontoon and secure the requisite stability. In addition, there are movable caissons or end gates, which are only used when it is necessary to increase the lifting power. Of the five pontoons, the three middle ones are rectangular, while the end ones are pointed at the ends; all are uniformly 87 feet 11½ inches wide, the middle ones being 75 feet, the end ones, 108 feet 4 inches long. A space of 2 feet is left between the pontoons, which lie wholly between the side walls, to which they are strongly bolted. The length over all of the dock is 450 feet, the width between the broad altars, 82 feet, and the depth over the sill, 27.5 feet. When immersed to this extent, the dock draws 42.5 feet of water, the freeboard being then 4 feet 2 inches. The whole is designed so as to be self-docking. Any particular pontoon can be detached and docked for examination and repairs, while the underwater portions of the side walls can be got at by careening the whole structure. The pumping machinery, driven by electric motors, is capable of lifting the dock with a 10,000-ton ironclad on board in 2½ hours, and is in duplicate. The tanks which control the flotation are thirty in number, each pontoon being divided up into four water tight compartments, while the walls below the engine decks are each divided into five such compartments.

The dock was towed out to Havannah. It was fitted with a foremast and square sails, and with a jigger mast aft, whilst steam steering gear and other appliances requisite for the voyage were installed.

The following table gives the principal data of the two docks.

	Hamburg Dock.	Spanish Dock.
Length, feet	560	450
Breadth, feet	88	82
Depth over the sill, feet	30	27.5
Draught of water, feet	47	42.5
Freeboard, feet and inches	4	4–2
Lifting power, tons	17,500	10,000
Time for lifting maximum load, hours	1	2½

LIQUID FUEL.

[Extract from a paper by R. WALLIS, read before the North-East Coast Institution of Engineers and Shipbuilders.]

The writer, whose experience with liquid fuel has principally been with petroleum residues on board of steamships, says that several attempts have been made to spray the oil by other means than that of the steam jet, in order to overcome the difficulty of making up the fresh water drawn from the boilers in the form of steam.

Air under pressure, especially if heated, has been found to give good results, but the flame is shorter, giving a more intense heat for a short distance than the flame from a steam sprayer. More air than steam is required for the spraying of the oil, and the air jets are more noisy than the steam. The danger of an explosion of oil gas in the furnace and combustion chamber when lighting up, especially if the furnace has been stopped for a short time only, is very much greater with air than with steam sprayers.

Comparing the economy of air and steam sprayers (notwithstanding the drawback of having to make up the water lost in steam used by the sprayers), the steam sprayers appear to be the most economical, and are certainly the type mostly in use. The arrangement of the whole of the steam sprayer installation is exceedingly simple and not liable to derangement or breakdown, whereas the compressed air system is complicated and the risk of breakdown increased by the addition of the air compressor.

In relighting a furnace, which has been extinguished for a short time, lies the greatest danger of explosion of oil gas and

the accompanying back flash from the furnace doors. Any small leakage or drip of oil finding its way into the heated furnace gasifies and forms an explosive mixture with the air, and, if the lighting-up torch is introduced into a furnace under these conditions, an explosion is sure to take place, and the person introducing the torch is very possibly burnt. Before lighting a furnace, it should be well blown through with steam, and care taken to see that the steam jet is opened first and the torch placed in the furnace before the oil valve is opened, in order that the spray may ignite as soon as it enters the furnace. If these precautions are taken, there is not the slightest danger of explosions, even if fuel with a low flash point is used.

The result obtained by several experimenters, that the average evaporation of liquid fuel is twice that of coal, has been confirmed by a long series of experiments conducted by the writer under the instructions of the Wallsend Slipway and Engineering Company, Limited, with various sprayers.

The boiler, which is of the ordinary marine type, evaporated with coal fuel from seven to eight pounds of water from and at 212 degrees Fahrenheit for each pound of coal burnt, the uptake temperature being about 650 degrees Fahrenheit. With Russian astatki, the evaporation was from 13 to 16 pounds from and at 212 degrees Fahrenheit per pound of oil. The following are the average data from some experiments with a Rusden and Eeles sprayer, and a heat account from the same data.

Kind of liquid fuel	Russian astatki.
Specific gravity	.9
Chemical analysis (approximate):	
Carbon, per cent	87
Hydrogen, per cent	12
Oxygen, per cent	1
Temperature of stokehold, degrees Fahrenheit	60
escaping gases, degrees Fahrenheit	450
Weight of steam required to spray one pound of oil, pound	.3

Assuming that the air contained 23 per cent. of oxygen, and that the excess of air over that required for complete combustion passing into the furnace was 20 per cent., which would be about

correct, because the slightest reduction of air caused smoke to issue from the chimney.

		Heat units.		Equivalent evaporation from and at 212° Fahr.
Total heat from combustion of 1 pound of oil—				
Carbon, .87 × 14,500	= ...	12.615		
Hydrogen, .12 × 62,032	= ...	7,444		
			20,059	20.7
Heat cost in waste gases at 450 degrees Fahrenheit—				
Carbonic acid gas	3.19 pounds...	269		
Nitrogen	10.72 pounds...	909		
Water vapor from cumbustion	1.08 pounds...	1,452		
sprayer	.30 pounds...	29		
Surplus air, 20 per cent	2.78 pounds...	257		
			2,916	3.0
			17,143	17.7
Heat lost in radiant heat, etc.			1,687	1.7
Heat absorbed by water in boiler			15,456	16

In addition to the petroleum oils, the following oils have also been used as fuels :—Shale oil, blast furnace oil, creosote, green and other tar oils.

TABLE I.

	Specific gravity.	Chemical composition.						Heating Power, British thermal units.	Theoretical evaporation.		Evaporation in pounds from and at 212° Fahr. by experiment.
		Carbon.	Hydrogen.	Nitrogen.	Sulphur.	Oxygen.	Ash.		Pounds from and at 212.	Pounds air required per pound fuel.*	
		Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.				
Petroleum—											
Pennsylvanian heavy crude...	.886	84.9	13.7	...	...	1.4	...	20,736	21.48	14.56	...
Caucasian light crude	.884	86.3	13.6	...	...	0.1	...	22,027	22.79	14.74	...
heavy crude	.938	86.6	12.3	...	...	1.1	...	20,138	20.85	14.28	...
refuse	.928	87.1	11.7	...	...	1.2	...	19,832	20.53	14.12	16
Crude average, 15 samples	.870	84.7	13.1	...	...	2.2	...	20,233	20.94	14.29	...
Refined average	.760	72.6	27.4	...	...	...	...	27,531	28.5	17.93	...
Scotch blast furnace oil	.920	83.6	10.6	...	0.1	9.4	...	18,590	19.2	17.93	...
Coal—											
Welsh, 37 samples	1.315	83.8	4.8	1.0	1.4	4.1	4.9	14,470	14.98	...	9.05
Newcastle, 18 samples	1.256	82.1	5.3	1.3	1.2	5.7	3.8	14,432	14.94	...	8.01
Derbyshire and Yorkshire, 7 samples	1.292	79.7	4.9	1.4	1.0	10.3	2.6	13,582	14.06	...	7.58
Lancashire, 28 samples	1.273	77.9	5.3	1.3	1.4	9.5	4.9	13,552	14.03	...	7.94
Scotch, 8 samples	1.260	78.5	5.6	1.0	1.1	9.7	4.0	13,804	14.29	...	7.70
Average British, 98 samples...	1.279	80.4	5.2	1.2	1.25	7.87	4.0	13,968	14.46	11.34	8.13

*Assuming that air contains 23 per cent. of oxygen.

Comparing the value of coal and oil as fuel, it will be found to vary considerably according to the quality of the fuel, and the circumstances under which each are burnt, oil doing from 1½ to 2½ times the work of an equal weight of coal; taking the average conditions, the results of extended experience with astatki and crude petroleum show that these oils will be found to do twice the work of coal.

Table I shows the analysis of various oils and coals, together with their calculated calorific and evaporated values. This shows a value for oil of only 1½ times that of coal, and, therefore, some course other than that of comparative heat value must be looked for to account for the result of a value of two to one in favor of oil fuel, which is found in practice. This difference may be accounted for to a great extent by the following causes.

1. The combustion of the liquid fuel is complete, whereas that of coal is not, consequently in the former case there is no lost heat in smoke or soot.

2. There are no ashes or clinkers, and consequently no fires to clean with the accompanying loss of heat and drop in the steam pressure. The steam pressure and revolutions of the engines being maintained at one point throughout the voyage.

3. The boiler tubes are always free from soot and clean, and, therefore, always in the best condition for transmitting the heat from gases passing through them to the water of the boiler.

4. The temperature of the escaping gases may be considerably lower than is required to create the necessary draft for coal firing. With coal, the air has to be drawn through the bars and the fire in the furnaces; by natural draft, this requires a temperature of the escaping gases about 600 degrees to 700 degrees Fahrenheit. But in the case of liquid fuel there are no bars or thick fire for the air to force its way through, and the required amount of air can be drawn through the furnaces by a much lower uptake temperature—about 400 degrees to 450 degrees Fahrenheit being in most cases sufficient.

5. The admission of air being under complete control, and the fuel being burned in fine particles in close contact with the oxygen of the air, only a very small excess of air above that actually

necessary for the complete combustion of the fuel is required. With coal, in order to ensure as complete combustion as possible, a very much larger excess of air is required.

(NOTE.—The advantages, other than the calorific advantages given above, and disadvantages of liquid fuel were given in a paper on page 744 of Volume VII.—EDIT.)

THE CURTIS STEAM TURBINE.

(Extract from Prof. Jas. E. Denton's Report of Test.)

The turbine consists of two rings of curved buckets or blades, about 45 inches diameter, which are mounted upon discs revolving with the shaft. Between the two revolving rings is a group of curved blades occupying a short circular segment, which are fixed to the cylindrical drum, forming the turbine case. Steam is delivered to the first ring of revolving blades by a single nozzle, and expends part of its expansive energy upon this ring. It then passes through the fixed blades and acts again, by a further expenditure of expansive energy, upon the second ring of revolving blades.

By this compound action of the steam upon two discs, a high degree of economy is available at speeds of rotation which enable dynamos to be directly connected to the turbine, without the use of the reduction gearing necessary with a single disc, and a perfectly noiseless operation is secured. The low speed of rotation secured, coupled with so high a degree of economy, is a very valuable feature, considering the turbine as a competitor of the piston engine in commercial practice. The low speed of rotation also makes unnecessary any special proportions or adjustments of the shaft of this turbine in order to avoid objectional vibration of the disc, due to the fact that the center of gravity of the latter may not be located at its axis. The most novel and important feature of the turbine lies, however, in the steam nozzle, which is of rectangular cross section, so that one side of it can slide under the action of the governor without altering the ratio between the initial special cross section of the nozzle, and thereby adjust the quantity of steam delivered to any load without altering the ratio

of expansive energy of the steam. By this means, the loss of economy due to the throttling action of the governor upon the steam in other turbines is avoided, and a means of automatically controlling the motor at uniform speed under all variation of load is secured, which is not only highly efficient as regards economy but is of extreme simplicity. Provision is also made for quickly adjusting the motor to operate either "condensing" or "non-condensing" with the same horse power by hinging one side of the nozzle, so that by turning a hand crank the width of the throat of the nozzle is altered in a moment without interfering with the action of the governor or stopping the machine. This is an important feature for practical service, as many power stations have to frequently operate condensing engines without a vacuum on account of a temporary deficiency of condensing water. The use of a single steam nozzle delivering to five or more buckets, as in this turbine, is also advantageous to economy as compared to the use of several nozzles, each of which delivers to a smaller group of buckets, as the "spill" or leakage of steam at the ends of the group of buckets is a greater percentage of waste in the latter case.

The turbine was set up for test on the premises adjoining the Third Avenue Power House of the Nassau Electric Railway, at Third avenue and First street, Brooklyn. Its power was absorbed by a visco-dynamometer consisting of two 24-inch steel saw blades fastened to the shaft of the turbine which revolved within a cylindrical drum kept partly filled with water. The friction between the revolving saw blades and the water afforded a steady resistance similar to that of a dynamo armature. The resistance was measured by weighing the tendency of the cylindrical drum to rotate, with a spring balance, the drum being supported on roller bearings so that it was sensitive to within about one per cent. of the least power developed. Steam was supplied to the turbine from the boilers of the power house through an uncovered 4-inch pipe about 50 feet in length, and, after passing through the turbine, was condensed in a Wheeler surface condenser from which it was withdrawn by an air pump and weighed. The steam driving the air pump and a pump supplying circulat-

ing water to the condenser was taken from the steam main before the latter reached the turbine and was exhausted into the atmosphere from the pumps. The scales and spring balance were calibrated by standardized weights. The revolutions were measured by a continuous counter positively connected to the shaft of the turbine. Tests were made to determine the horse power developed and steam consumed at various loads, with the turbine operated both "condensing" and "non-condensing," with the following results.

	Condensing.			Non-condensing.		
	Full load.	Half load.	Third load.	Full load.	Half load.	Third load.
Pressure below throttle valve, pounds per square inch above atmosphere	129	131	129	128	130	132
Vacuum in condenser, inches of mercury	26.8	27.5	27.5	.....	.....	.....
Pressure in condenser, pounds per square inch above atmosphere	.....	.....	.....	1.9	1.5	2
Revolutions per minute	2760	2778	2781	2587	2533	2453
Brake horse power	122.8	68.2	39.3	177.1	88.7	58.9
Pounds water per hour per brake horse power	23.8	24.7	27.2	34.7	38.2	43.1

The horse power available from the turbine, either condensing or non-condensing, might be any amount up to the strength limit of the wheel and shaft, according to the size of the steam nozzle which supplies steam to the wheel. As constructed for the tests, the nozzle limited the power to the above maximum figures, but this size of turbine might, with a larger nozzle, develop 175 H.P. as a maximum operating "condensing," and 250 H.P. "non-condensing," with the same or better economy of steam. We may therefore compare the water consumption figures and the dimensions of this turbine with those for a reciprocating high speed steam engine of 150 rated horse power "condensing," and 225 horse power "non-condensing." A 225-horse power non-condensing reciprocating engine will be represented by a single cylinder 18 inches diameter, 20 inches stroke, running at 200 revolutions per minute, using steam at about 90 pounds boiler pressure, and a compound engine, by cylinders 15 × 24 inches by 18 inches stroke, running 200 revolutions per minute, using steam at about 125 pounds boiler pressure. A 150-horse power condensing engine for first class practice will be represented by a compound

engine having cylinders about 11 × 20 inches × 15 inches stroke, running at 230 revolutions per minute with about 125 pounds water pressure. The water consumption of such engines per brake or useful horse power would be as follows, assuming the power absorbed by friction to be for the simple engine 5, 8.76 and 12.45 per cent. of the rated horse power, for full, one-half and one-third load respectively, and 8, 14 and 20 per cent. for the compound engines.

	Pounds water per hour per brake H.P.		
	Full load.	Half load.	Third load.
Single cylinder engine, non-condensing.....	33.3	37.3	45.5
Compound non-condensing engine.....	25	30	34.8
Compound condensing engine.....	19.7	23.6	27.4

It may be concluded, therefore, that when operated without a vacuum, that is "non-condensing," the average economy of the turbine in its present degree of perfection is practically equal to that of non-condensing high speed simple reciprocating engines, but that it consumes about 30 per cent. more steam per horse power than a compound non-condensing reciprocating engine, and, when operated with a vacuum or "condensing," about 7 per cent. more steam than a reciprocating engine. The turbine, however, weighs about 4,000 pounds, or 33 pounds per rated horse power "condensing," and 18 pounds per rated horse power "non-condensing," while the simple reciprocating engine weighs about 30,000 pounds and the compound engine about 40,000 pounds. Per horse power the reciprocating engine weights are 130 pounds for the simple non-condensing engine, 180 pounds for the compound non-condensing engine and 200 pounds for the compound condensing engine. Again, the space occupied by the turbine is about 4 feet of width, 5 feet of height by 4 feet of length, while the simple reciprocating engine occupies about 10 feet of width, 7 feet of height and 14 feet of length, and compound engines occupy about 50 per cent. more length if of the tandem type, or a greater width if of the twin type. Furthermore, the turbine requires practically no foundation, the one under notice having been operated without

sensible vibration and without any noise, while resting on a platform built of light boards several feet above the ground. These advantages of the turbine, in view of the fact that its construction requires no special mechanical skill different from that required for a reciprocating engine, and that the skill required to operate it is certainly less than that required with reciprocating engines, make it fairly certain that even if no better economy could be obtained than is shown by the above figures, it will find a ready market in competition with reciprocating steam engines for electrical and many other purposes, especially if it is marketed at prices involving a reasonable percentage of profit over its cost of production. I have no doubt, however, that considerable improvement in economy may be made in future constructions of this turbine. For, a careful study of the distribution of the expansive energy of the steam, by the aid of data obtained during the tests regarding the pressures existing throughout the steam passages, makes it fairly certain that by adopting different proportions for the blades of the fixed and second revolving rings, so as to secure a more complete expansion of the steam in the second revolving ring of blades, the economy may be increased about 21 per cent. This would make the water consumption under condensing conditions with full load about 18.6 pounds per hour per actual shaft H.P., and 27.4 under non-condensing conditions with full load. This would be equivalent to about 17 pounds per indicated horse power, for a compound condensing engine.

The same circumferential speed of blades as existed in the turbine tested, can be applied to different diameters of disc so as to secure different amounts of horse power with the above economy, and practically the same weight of motor per horse power. The speed of revolution corresponding to various horse powers may be as follows.

Diameter of wheel.	Revolutions per minute.	Shaft horse power.
3.2 feet.	3,000 revolutions.	50 horse power.
3.4 feet.	2,750 revolutions.	100 horse power.
3.8 feet.	2,500 revolutions.	150 horse power.
4.7 feet.	2,000 revolutions.	300 horse power.
6.3 feet.	1,600 revolutions.	500 horse power.
7.1 feet.	1,350 revolutions.	1,000 horse power.

CONCLUSIONS.

1. The tests and study of this turbine show that its economy may be practically equal to that of the best high speed reciprocating engines, while its weight is from one-sixth to one-tenth of the latter per horse power.

2. It is automatically governable under variations of load without throttling the initial steam pressure, so that its decrease of economy at fractional loads is less than that of the best steam turbines now in the market.

3. It can be quickly adjusted to operate either "condensing" or "non-condensing" to develop the same horse power, without stoppage or interference with the action of the governor.

4. It offers the highest degree of economy yet available from steam turbines at much lower speeds of rotation, thereby avoiding the use of reduction gearing, to apply the power of the turbine by direct connection to dynamos, within the limits of satisfactory speed for general commercial service.

5. The avoidance of the use of gears also secures a more noiseless operation of the turbine.

SHIPS.

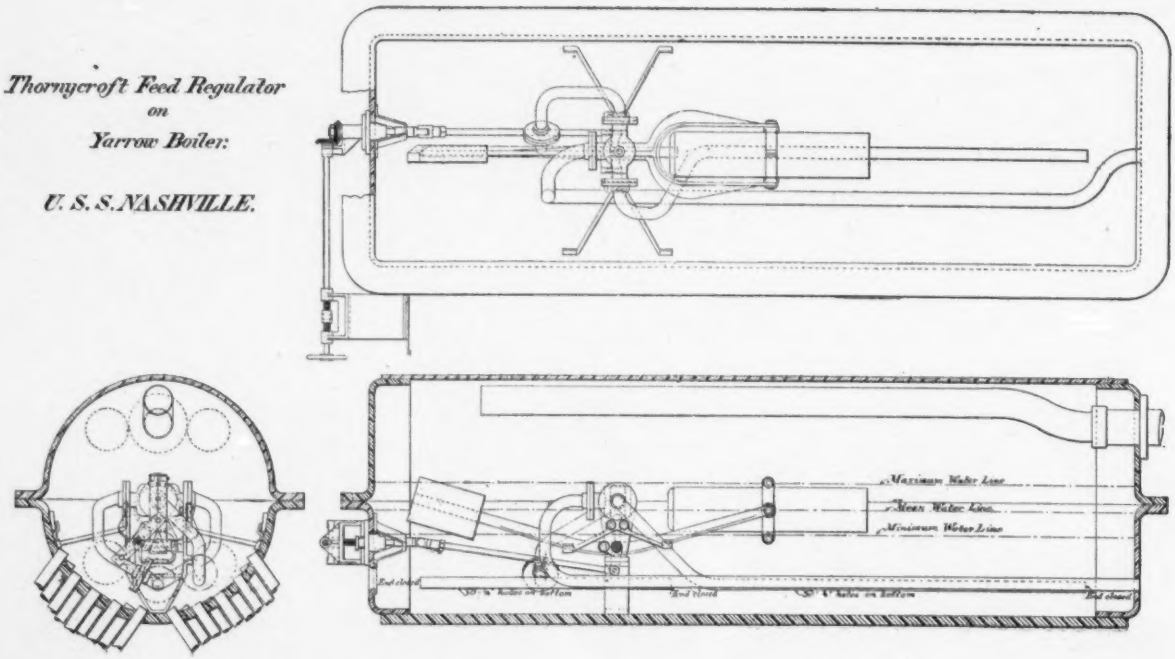
UNITED STATES.

Nashville.—The following additional notes on the contract trial of this gunboat, published on page 574 of the August number, were kindly sent to the JOURNAL by P. A. Engineers W. Strother Smith and C. B. Price, U. S. N.

(1) The Yarrow boilers were not fitted with distance pieces or baffle plates. (2) Dampers were fitted in their uptakes but were kept wide open during the trial. (3) The two types of boilers, Scotch and Yarrow, were entirely disconnected on the trial; the Yarrow boilers delivering steam to the H.P. cylinders, and the others, to the 1st I.P. cylinders. The ratio between the two pressures was kept practically constant by means of a $1\frac{1}{2}$-inch branch from the main steam pipe (Yarrow) to each 1st I.P. valve chest. This required the constant attention of one man during the trial. (4) The firing was done by able men who had fired the Yarrow boilers on the preliminary trials and on the contractors' run two days previous to the official trial. The fires were carried moderately heavy, 10 to 14 inches thick, evenly distributed over the grate. The draft was introduced from the back and distributed under the grate by baffle pieces. The air pressure allowed was 2 inches, but only 1.26 inches was obtained as the average for the trial. Each boiler was fired at regular intervals, from eight to nine minutes between each charge, and the rotation of firing, slicing and breaking up was continuous during the whole trial. (5) One man tended water for the Yarrow and another for the Scotch boilers, and the two types were fed and fired entirely independent of each other. The Yarrow boilers were fed by a feed pump situated in the fire room, and for the first hour, the throttle of this pump was continually altered; after that it required but little attention, the feed regulators and an occasional setting of the feed check being all that was required. The

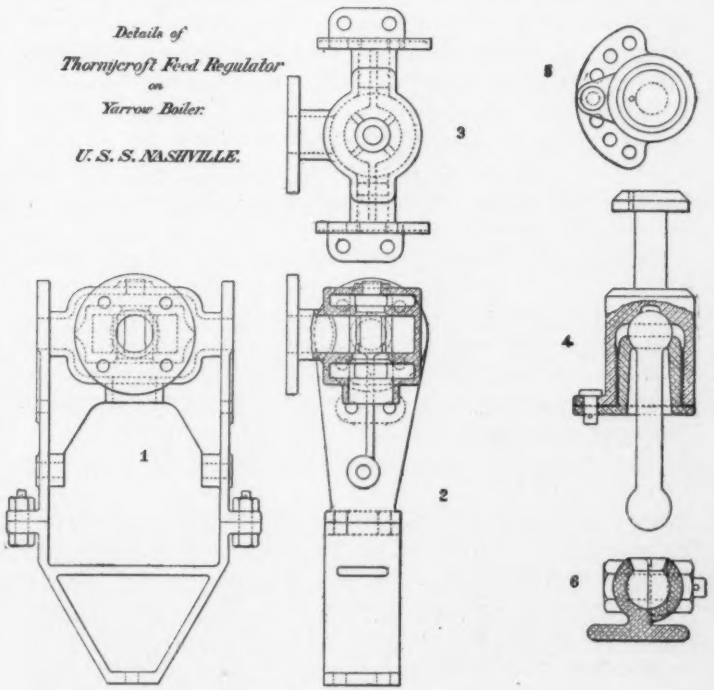
Thornycroft Feed Regulator
on
Yarrow Boiler:

U. S. S. NASHVILLE.



water tender on the official trial was a man of ability and wide experience.

The Feed Regulator.—As previously described, each of the four Yarrow boilers has an automatic feed regulator of the Thornycroft patent. This consists of a lever balanced near the middle, on one end of which is a float and on the other, a counterbalancing weight. This is shown in the general cut giving the arrangement inside of the steam drum. A series of connections near the fulcrum actuates a small double poppet valve, through which the feed water enters the boiler. The height of the water, for various rates of steaming, is regulated by a connection on the outside, which, by shifting the fulcrum of the balanced lever,



controls its motion and consequently that of the feed valve. When the water rises, the float is carried up and closes the poppet valve, and vice versa when the water gets low. The feed pump is run continuously, slowing or starting as the need requires.

In the cut of the details, figures 1, 2, and 3 show the feed valve chamber and its support, the chamber being shown in section in figure 2. The support, as attached to the steam drum, is also shown in the cross section of the steam drum. Figure 4 is an enlarged view of the double poppet feed valve, and the ball and socket joint link which connects the feed valve to the balanced float lever. The valve opens downward, so that in case of an accident the valve will fall by gravity and leave the ports open. Figure 6 is a section of the lower socket, one-half of which is part of the float lever, and the other half, detachable. Figure 5 is a plan of figure 4.

[NOTE.—The hole through the feed valve in figure 4 is not part of the original Thornycroft regulator, but was put in by the builders of the vessel. The designers of the regulator claim that the efficient working of the regulator may thereby be destroyed, and that this hole should be closed.—ED.]

Bailey, Goldsborough and Stringham.—These are the names of torpedo boats *Nos. 21*, *20* and *19*, respectively, which were described on page 597 of the August number.

Plunger.—This submarine boat, built from the designs and under the supervision of the John P. Holland Torpedo Boat Company, by the Columbian Iron Works and Dry Dock Company, Baltimore, Md., was successfully launched on August 7. The JOURNAL will publish an extended description of this boat in the February number.

Revenue Cutter No. 6.—Bids were opened at the Treasury Department, on October 21, for the construction of a new steel Revenue Cutter, which is intended for service on the Atlantic Coast, and to have headquarters at New York City. The new cutter will be 188 feet long over all and 170 feet between perpendiculars; 29.5 feet breadth of beam moulded; 16.5 feet deep; and at a mean draught of 10 feet will displace 706 tons. She will

be rigged as a two-masted schooner, with pole masts. There will be one triple expansion engine of the vertical, inverted, direct-acting type, having cylinders 20.75, 32 and 50 inches in diameter, with a common stroke of 27 inches. Steam will be supplied by two single-ended Scotch boilers, each 13 feet outside diameter by 10 feet long over all. The air and circulating pumps will be independent. At 170 revolutions it is expected that the engine will develop 1,500 I.H.P., which will give a speed of about 15.5 knots. The limit of the appropriation is $175,000. The following bids were received, and the contract will undoubtedly be awarded to the Columbian Iron Works, of Baltimore, who guarantee to deliver the vessel on or before July 25, 1898. The Columbian Iron Works & Dry Dock Co., $141,000; Gas Engine & Power Co. and C. L. Seabury Co., $151,800; Lewis Nixon, for The Crescent Shipyard, $173,900; The Chas. Hillman Ship & Engine Building Co., $173,000.

ARGENTINE REPUBLIC.

Presidente Sarmiento.—This training ship, built by Messrs. Laird Bros., Birkenhead, was successfully floated out of the building dock on August 31.

The length is about 270 feet; beam, 43 feet; draught, not over 20 feet; displacement, about 2,750 tons. The hull is of steel, sheathed, and has 24 principal water tight compartments. The stem, stern and rudder frame are of bronze. The vessel is ship-rigged, and has a Bevis feathering propeller.

The armament will consist of five 4.7-inch rapid fire guns; two 14, four 6 and four 3-pounder rapid fire guns; some machine guns, and three torpedo tubes. Electric ammunition hoists will be fitted.

The engine is of the direct-acting, triple expansion type, and is expected to give the vessel a speed of 13 knots. There are four main boilers, two Niclausse and two cylindrical, each pair in a separate compartment, and an auxiliary boiler. Workshops, fitted with suitable machine tools, are installed for the instruction and use of the cadets and apprentices.

AUSTRIA.

Zenta.—This torpedo cruiser, similar to the *Jaguar*, described on page 405 of the May number, was successfully launched at Pola on August 18. The following particulars are from "Mitt-heilungen aus dem Gebiete des Seewesens," Pola.

The length is 314.9 feet; beam, 38.39 feet; draught, half load, 13.94 feet; load displacement, 2,289 tons. The hull is of Siemens-Martin steel, with a protective deck. Bilge keels are fitted. The vessel is brigantine-rigged, the total sail area being 6,308 square feet, or about fourteen times the area of the immersed midship section, which is 451.33 square feet.

The armament will consist of eight 4.7-inch nickel steel, and ten 1.85-inch rapid fire guns; two machine guns; and several 17.72-inch torpedo tubes.

The twin screw, vertical, four-cylinder, triple expansion engines were built by the Stabilimento Technico, Trieste, and have cylinders 28.74, 43.3 and (2) 47.2 inches in diameter, the stroke being 26.77 inches. They were designed to develop 7,100 I.H.P., under forced draft and with the full load, when running at 190 revolutions per minute, and to give the vessel a speed of 20 knots. There is one condenser for each engine, the total cooling surface being 2,019.4 square feet. The propellers are three-bladed, of bronze, 12 feet in diameter, and have a mean pitch of 14.23 feet.

There are eight single-furnace Yarrow boilers (as mentioned on page 601 of the August number), in equal groups in two compartments, with a smoke pipe for each group. The total grate surface is 350, and the heating surface, 20,000 square feet. The working pressure will be about 215 pounds per square inch, and they are to supply the steam for full power with 1 inch of air pressure. There are eight main and four auxiliary feed pumps in the fire rooms, all of the Worthington type. Eight blowers supply the forced draft.

The total weight of machinery, including water in boilers, condensers and pipes, is 527.5 tons. The bunker capacity is 464.5 tons of coal. There are three dynamos for lighting the

VOLKA
XU

"INJENIERO HYATT."

vessel and the two search lights. There is a smaller dynamo for the 4,000 candle power search light in the steam launch.

BULGARIA.

———. This torpedo despatch boat is building at Bordeaux, France. The length will be 231 feet 8 inches; beam, 27 feet 2 inches; displacement, about 700 tons. The twin screw, triple expansion engines are to develop about 2,600 I.H.P. and give the vessel a speed of 17 knots.

CHILI.

Injeniero Hyatt.—This first class torpedo boat, one of the six built by Messrs. Yarrow & Co., and described on pages 144 and 406 of the current volume, left Plymouth, England, on April 28 and arrived at Talcahuana, Chili, on June 28, having made a successful passage, although during part of her run she encountered very bad weather. On arrival, she went through an official trial with success, and on the examination of the boilers and the machinery everything was found in perfect order and quite satisfactory to the Chilian authorities.

The JOURNAL is indebted to Messrs. Yarrow & Co. for the accompanying cut of the boat and the following information.

The single screw engine has cylinders 18, 26 and 39 inches in diameter and a stroke of 18 inches.

There are two Yarrow straight tube boilers, the combined weight of which, including water and fittings, is 18 tons. They furnish steam for about 2,000 I.H.P. The propeller is 7.5 feet in diameter.

On the official trial on February 15, the draught forward was 2 feet 7.5 inches, aft, 4 feet 1.5 inches, and mean, 3 feet 4.5 inches. The load on trial was 27 tons. The results, from the last four runs over the measured mile on the Maplin, were as follows.

Steam pressure in boilers, 192, in first receiver, 84.5, and in second receiver, 14.6 pounds per square inch; vacuum, 24 inches; revolutions per minute, 362.75; speed, third mean, 27.219 knots; slip of propeller, 5 per cent.; air pressure, 1.25 inches of water.

The mean number of revolutions per minute for the three

hours was 355.4, giving a mean speed of 26.67 knots for the whole run.

After the three hours' speed trial, circles were turned to starboard and to port in a space equal to about three times the length of the vessel. The engines and boilers worked well.

CHINA.

Hai Yung.—The first of the three cruisers building at Stettin, Germany, by the Vulcan Works, was successfully launched on September 15. The principal data of these vessels were given on page 612 of Volume VIII. The length is 328 feet; beam, 41 feet; depth, 27 feet 7 inches; draught, with full load and about 220 tons of coal, 16.4 feet; corresponding displacement, 2,903 tons; I.H.P., 7,397; speed, 19.5 knots. The armament will consist of three 5.9-inch, eight 4.13-inch and six 1.46-inch rapid fire guns; six Maxim machine guns; and three torpedo tubes.

EGYPT.

Sheikh and **Sultan.**—These light draught gunboats for the Nile were built by Messrs. Yarrow & Co., Poplar. The *Sheikh* was launched on October 13. The JOURNAL is indebted to the courtesy of Messrs. Yarrow & Co. for the following description and the accompanying cut.

The vessels are 145 feet in length by 24 feet 6 inches beam. The hull proper is 6 feet deep and carries a superstructure, as shown in the illustration. The draught is 2 feet when carrying a load of 35 tons. The hull is built in eleven floatable sections, which can be easily put together while afloat, thereby avoiding the difficulties and delays incidental to riveting together and launching, and also avoids the necessity for a large number of skilled hands. The machinery consists of twin screw, compound, surface-condensing engines, supplied with steam by two Yarrow straight tube water tube boilers.

The design illustrated was got out at the request of the Egyptian government by Sir William White, and it will be seen that it embodies a thoughtful and well-matured scheme. It will be recollected that Messrs. Yarrow & Co., about ten years ago, built

a number of shallow draught stern wheel gunboats for the Nile Expedition. These vessels proved very successful at the time and still more so during last year, when they took a leading part in the advance towards Khartoum.

But the advisers of the Egyptian Government determined that vessels capable of carrying guns of greater power at a higher level would be desirable. It was decided, therefore, that stern wheelers were not desirable if any other means of propulsion equally efficient could be devised, because in the case of stern wheel machinery the engine room and stoke hold staff, as well as the boiler and engines, are necessarily much exposed. It was also essential that the vessels should be capable of being shipped to Egypt and transported by rail to the Upper Nile; and, to avoid the delay and difficulties incidental to riveting-up and launching, it was determined to have the sections floatable, as the risk of passing the cataracts if the vessels went out whole would be altogether prohibitory. This system of construction in floatable sections was first introduced by Messrs. Yarrow in a stern wheeler built by them for the King of the Belgians for the navigation of the Congo.

To get the necessary result as regards propulsion, ordinary screws would not be advisable, and Messrs. Yarrow & Co. had recourse to a device which they have adopted successfully for some years. In the bottom of the boat, near the stern, two tunnels are raised, and in each of these one of the twin screw propellers revolves. These propellers are of special design. The upper part of the tunnel is as much as 2.5 feet above the water line. The working of the screws drives any air that may be present out of the tunnels, and its place is immediately taken by water. As the space within the tunnels above the water line is wholly shut off from the surrounding atmosphere, the water itself, as it were, seals this air tight compartment, and the tunnel remains full of water, just in the same way that a syphon, when once filled, does not empty itself. The screws, therefore, are wholly immersed. On trial, the speed was found to be a trifle over 13 miles an hour, and the draught of water, 1 foot 11½ inches.

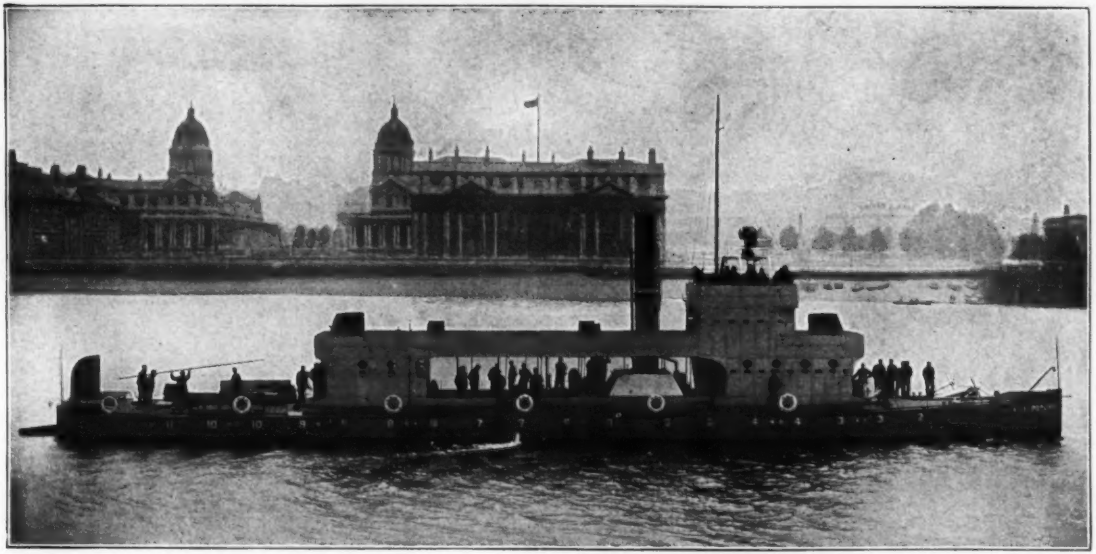
This arrangement of propellers offers a considerable advantage

in the fact that the screws can be taken off and replaced while the vessel is afloat. This is effected by means of a moveable cover which is placed on the top of the tunnel immediately over the propeller itself. By opening this, the water in the tunnel at once falls to the general water level surrounding the vessel, and the screw is consequently more than half out of water. The propellers are not likely to get damaged, because they do not work below the bottom of the boat and are surrounded on all sides by the hull itself; yet it is an immense advantage to be able to get at them quickly when necessary. On a trial, made specially to test the time occupied in removing the propeller and replacing it by another, it was found that this could be readily done in eight minutes.

This system of propulsion offers exceptional advantages for going astern, or what is the same thing, stopping headway; in fact, it was found on the trial, that from full speed ahead to a state of rest, the vessel would only travel about two lengths. This power of going astern is of the utmost value when navigating rivers which are shallow, the beds of which are continually changing; because, on going down stream, it is clearly necessary on approaching a shoal to stop the vessel as quickly as possible.

A distinctive feature of these boats is the fitting of lee boards in the fore part, to take the place of "dead wood," which is necessarily absent in a flat-bottomed craft drawing only two feet of water. These lee boards perform exactly the same function as those in a Thames barge, which by their lateral resistance, prevent the vessel blowing off to leeward. Light, high-sided vessels are extremely difficult to handle when there is a side wind, and, to make them handle and manœuvre easily, lee boards are required. The steering, when going ahead, is so rapid that lee boards need not be used; only when going astern are they required. The steering is arranged by means of three rudders, worked by steam gear.

The superstructure consists of two deck houses, as shown. These are connected by a flying bridge, 38 feet long by 13 feet wide, while above this is a bridge deck, 14 feet long by 13 feet wide, and above this again is a platform on which is fixed a



"SULTAN," LIGHT DRAUGHT GUNBOAT FOR THE NILE, BUILT BY MESSRS. YARROW & CO., POPLAR.

searchlight. The deck houses and the central portion of the vessel are made of chrome steel, and the parts surrounding the boiler and engine are of such a thickness as to be proof against the Lee-Metford bullets at 20 yards point blank. The bulwarks of the flying deck also are of the same material, and the cabin sides are loop-holed for rifle fire.

The armament consists of two 12-pounder, quick firing guns, placed at each end of the flying deck, the bulwarks being hinged so as to fold down at the ends to form an extension of the platform when the guns are to be used. On the flying deck also are four automatic Maxim guns, two on each side. Four similar guns are placed in the upper battery or bridge deck, and are 21 feet above the water line. At this level, it is anticipated that these guns will have perfect range over the banks on each side of the Nile.

The name of the first vessel built is now the *Sultan*, but she was originally known as the *Poplar*. She has already been sent out to the Nile and is probably by this time half-way between Cairo and Abu Hammed, where she is to be put together.

It may be added that these vessels are calculated to be able to carry, on an emergency, 1,000 troops. There is little doubt that before long we shall hear of the part that these vessels will play in the operations against the Mahdi on the Upper Nile.

ENGLAND.

Cæsar.—This first class battleship, mentioned on page 810 of Volume VIII, has completed the official trials. The following data are from the London "Times."

On October 7, the eight hours' natural draft trial was made in the Channel. The weather was fine and the sea smooth. The draught forward was 25.75 feet, and aft, 26.25 feet. Steam pressure in boilers, 148 pounds per square inch; vacuum, 27 inches; mean revolutions per minute, 96; I.H.P., 10,630; speed, 16.7 knots; air pressure, .27 inch of water.

On October 13, the four hours' forced draft trial was made. Draught forward, 25 feet 7 inches, aft, 26 feet 4 inches; steam pressure in boilers, 147 pounds per square inch; vacuum, starboard, 26.7, port, 27 inches; revolutions per minute, starboard,

101, port, 102.6; mean pressures in cylinders, H.P., 63, I.P., 33, L.P., 12 pounds per square inch; I.H.P., 12,652; speed, 18.7 knots; air pressure, .78 inch.

The thirty hours' coal consumption trial was completed on October 15, and consisted of a run from Spithead to the Lizard, and return. The draught forward was 25 feet 1 inch, aft, 26.25 feet; steam pressure in boilers, 142.3 pounds per square inch; vacuum, 26.25 inches; revolutions per minute, 87.86; I.H.P., 6,309; coal per I.H.P. per hour, 1.93 pounds; speed, 14.8 knots.

Vengeance.—This is the name of the battleship building at Barrow, and partially described on page 602 of the August number.

Canopus.—This first class battleship, referred to on page 408 of the May number, was successfully launched at Devonport on October 13. The launching weight was about 4,500 tons.

Powerful.—This first class cruiser, fully described on page 812 of Volume VIII, has completed a series of progressive trials. These trials were commenced on September 29, and were carried out by the vessel's force. The following results are from "Engineering," London.

REPORT OF PROGRESSIVE SPEED TRIALS OF H.M.S. *POWERFUL* IN STOKES BAY.

	4 runs at 10 knots.		4 runs at 12 knots.		4 runs at 14 knots.		4 runs at 16 knots.	
	Starbd.	Port.	Starbd.	Port.	Starbd.	Port.	Starbd.	Port.
Steam in boilers, pounds	227.5		230		225		230	
Vacuum, inches	26.1	26.75	26	26	26.0	26.2	25.9	26.2
Revolutions per minute	50.97	50.14	60.35	59.34	68.64	68.78	79.21	79.73
Mean pressure, high	20.75	18.02	29.7	25.72	34.15	34.22	45.87	45.62
intermediate	6.72	7.02	10.37	9.17	12.87	13.67	16.5	19.17
forward low	4.0	3.67	5.2	4.97	6.0	6.85	8.05	8.32
aft low	3.52	4.1	4.85	5.45	5.42	7.32	7.75	8.55
I.H.P., high	407	348	696	588	904	909	1403	1402
intermediate	320	329	591	508	824	880	1218	1464
forward low	224	203	347	325	453	518	702	730
aft low	198	227	325	355	410	554	675	750
Collective indicated horse power	1149	1107	1959	1776	2591	2861	3998	4346
Total indicated horse power	2256		3735		5452		8344	
Speed of vessel	10.591		12.492		14.223		16.206	

The *Powerful* is to go to the China station via Cape of Good Hope. Previous to leaving on her cruise, the commanding officer recommended (according to the "Practical Engineer,"

London,) that the engineer department be increased by 2 officers, 6 artificers and 66 men, making the total of that force 346 officers, artificers and men, and the total complement of the vessel 968, instead of 894. At present, there are on the vessel 8 engineer officers; 4 chief and 14 engine room artificers; 27 leading stokers, 1st and 2d class; 219 stokers and stokers, 2d class.

Arrogant.—This second class cruiser, mentioned on page 603 of the August number, has completed the official trials. The hull was built at the Devonport dockyard, and the machinery, by Earle's Shipbuilding Co., Hull. Owing to the strike in the engineering trade, the completion of the vessel has been delayed. From the same cause, the trials were made with naval ratings in place of the engine fitters belonging to the contractors. It may be mentioned that between the 2,000 and 7,000 H.P. trial, the main valves were reset.

Date of trial	Sep. 17–18.		Sep. 24–25.*		Sep. 30.†		Oct. 7–8.	
Length of trial, hours	30		30		8		30	
Steam in boilers, pounds per sq. in.	230		247		250		227	
at engines, pounds per sq. in.	210		240		244		.....	
Vacuum, inches	26.6		27.1		25.95		26	
	Stbd.	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*	*Stbd.*	*Port.*
Cut-off in H.P. cylinder, per cent	22.4	24.3	51	60	69.7	71	23.8	23.8
Revolutions per minute	88	86.9	128	127.4	141	140.7	...	...
Mean pressure in cylinder, H.P.	40.1	41.3	86.4	86.2	105	107	27.6	40.1
I.P.	15.8	12.7	35	34.7	39.7	43.9	14.2	14.3
L.P.	6.2	5.5	15.7	15.8	20.3	19.3	6	5.9
I.H.P., H.P. cylinder	369	375	1157	1147	1545	1575	332	351
I.P. cylinder	379	303	1225	1210	1689	1496	327	327
L.P. cylinder	390	341	1443	1442	1945	2040	364	356
collective	1138	1019	3825	3799	5179	5111	1023	1034
total	2157		7624		10290		2057	
Speed, knots	12.5		17.8		19.6		12.48	
Coal per I.H.P. per hour	2.84		2.101		.....		2.81	

* On this trial, the draught was 20 feet 4 inches forward, and 22.25 feet aft.

† On this trial, the draught was 20 feet forward, and 22 feet 1 inch aft.

The data of the four trials in the above table are from the London "Times." According to the "Naval and Military Record," London, the fourth trial was made at the expense of the Government, to determine the coal consumption under varying conditions. The same paper also gives the following table of the coal consumption for the fourth trial, saying that the cut-off in the H.P. cylinders was changed from time to time, and that the coal consumption was determined separately for the main and auxiliary engines.

Hours.	I.H.P.	Cut-off, per cent.	Coal for main engines.	Coal per I.H.P.	Coal for auxiliaries.	Total coal per I.H.P.
1–8.....	2,087	51.3	4,909	2.35	962	2.81
9–15.....	2,143	23.8	4,941	2.30	1,261	2.89
16–19.....	2,057	23.8	4,227	2.05	2,221	3.13
20–23.....	2,195	33.9	4,673	2.12	1,838	2.97
24–27.....	2,220	51.3	4,564	2.05	1,752	2.84
28–30.....	2,216	60.0	4,912	2.21	1,870	3.06

Although the mean results, deduced from this table, will not agree with those given in the first table, yet, as the details of the second make it appear reliable and valuable, it is published here.

Perseus.—This third class cruiser, built by the Earle Shipbuilding Co., Hull, and partially described on page 391 of Volume VIII, was successfully launched on July 15.

Pioneer and **Psyche.**—These third class cruisers, of the *Pelorus* type described on page 416 of the May number, have been ordered at the Chatham and Devonport dockyards, respectively. These vessels are two of the three proposed in this year's building programme.

Bramble, Britomart, Dwarf and **Thistle.**—The contracts for these four first class, twin screw gunboats, part of the building programme for 1897, have been let. The first two will be built by Messrs. Potter & Co., Queen's Dock, Liverpool, and the other two, by the London and Glasgow Shipbuilding and Engineering Co., Govan.

Condor and **Rosario.**—These two sloops are to be laid down at the Sheerness dockyard, under this year's building programme.

The length will be 180 feet; beam, 32.5 feet; mean load draught, 11.5 feet; displacement, 960 tons.

The armament will consist of six 4-inch and four 3-pounder rapid fire guns.

The engines are to develop 1,100 I.H.P. under natural, and 1,400 I.H.P. under forced draft, the corresponding speeds of the vessel being 12.6 and 13.25 knots.

Mallard.—This 30-knot torpedo boat destroyer, built by Messrs. J. I. Thornycroft & Co., Chiswick, and mentioned on

page 174 of the February number, completed the official trials on September 24.

On September 7, the coal consumption trial was made, the mean speed for the six runs over the measured mile being 30.794, and for the three hours, 30.201 knots. The mean steam pressure in boilers was 211 pounds per square inch; revolutions per minute, starboard, 398.1, port, 395.9; I.H.P., 5,749; air pressure, 2.87 inches of water. The coal consumption was 2.02 pounds per I.H.P.

The *Mallard* is the first destroyer to use the new Thornycroft arrangement for mixing the gases of combustion above the fires. This arrangement consists of a manifold of perforated pipes, one in front and the other at the back of the furnace, through which compressed air is forced in various directions into the combustion space above the fire. The results of the application of this arrangement were a remarkably low coal consumption per I.H.P., absence of flaming at the top of smoke pipes and very little smoke.

The three hours' speed trial, on September 24, resulted in a speed of 30.096 knots, as a mean for the six runs over the mile, and 30.115 knots for the three hours.

Chamois.—This 30-knot destroyer, built by the Palmer's Shipbuilding Co., and of which the preliminary trial data were given on page 606 of the August number, has completed the official trials.

An unsuccessful attempt was made on August 27, heated bearings stopping the trial just when the measured mile was reached.

On September 10, the three hours' coal consumption trial was made, the mean speed for the six runs over the mile in Stokes Bay being 30.026 knots with 388.8 revolutions per minute. For the three hours, the speed was 30.396 knots with 393.1 revolutions; steam pressure, 228 pounds per square inch; and air pressure, 2.75 inches of water. The coal consumption was within the limit. The wind was against the tide, the former influencing the speed very little. The tide had, however, a great influence,

as was shown by the mile runs, the lowest being at the rate of about 28, and the highest, 32.374 knots.

On September 23, the three hours' speed trial was made under peculiar circumstances, says "Engineering," London. Starting at 8·45 a. m., the engines had worked up to their required speed when the vessel had to return into harbor owing to a hot bearing. A new bearing was substituted, and the vessel started again, but the steering gear failed to answer, and it was found that a pin had been carelessly removed. This defect was made good, and the official trial again started at 2·25. On the measured mile, with 397 revolutions, a mean speed of 30.368 knots was maintained, and the mean speed for the three hours' run, with 394.4 revolutions, was 30.22 knots. When the vessel returned into harbor with a hot bearing, she had to ship fresh coal so as to restore her to her proper load, and this occupied some time.

On October 1, a coal consumption trial at 13 knots was made; owing to thick weather, the trial lasted 11¼, instead of 12 hours. The mean speed was 13.046 knots, and the coal per I.H.P. per hour, 1.86 pounds.

Bat.—This 30-knot torpedo boat destroyer, built by the Palmer's Shipbuilding and Iron Company, one trial of which was described on page 420 of the May number, has completed the official trials.

On July 7, the mean speed for the six runs over the measured mile was 30.053, and for the three hours, 29.78 knots. The mean steam pressure in the boilers was 230 pounds per square inch; revolutions per minute, starboard, 391, port, 400; I.H.P., 6,167; and air pressure, 3.3 inches of water.

On July 14, another trial was made with the contract load of 35 tons on board. The mean speed for the six runs over the mile was 30.229, and for the three hours, 30.165 knots; steam pressure in boilers, 250, at engines, 233 pounds per square inch; revolutions per minute, mean, 400; I.H.P., 6,189; air pressure, 3 inches of water. The coal consumption on this trial was within the 2.5 pounds per I.H.P. allowed by the contract, and, therefore, no extra weight had to be carried on the final speed trial.

This final trial resulted in a mean speed of 30.369 knots for the six runs over the mile, and 30.129 for the three hours.

Flying Fish.—This 30-knot torpedo boat destroyer, built by the Palmer's Shipbuilding and Iron Company, and mentioned on page 420 of the May number, made a preliminary contractors' trial on September 17.

For the six runs over the mile, the speed was 30.28, and for the three hours, 30.288 knots.

Thrasher and **Lynx.**—These torpedo boat destroyers, while steaming in line, with the *Thrasher* ahead, struck upon a ridge of rocks on Dodman Point. There was a dense fog at the time. Shortly after the *Thrasher* struck, a steam pipe in the forward fire room burst, killing three men and badly scalding two others, one of whom died in the hospital some time after. Both vessels were floated and afterwards docked at Devonport. The *Thrasher* was so badly damaged that she had to be towed, stern first, while the *Lynx* was able to reach port with her own engines.

The examination in dock showed that the *Thrasher's* bow and the plates behind the forward smoke pipe were twisted and doubled up; there was a large break across the hull abreast of the forward fire room. The main steam pipe of No. 1 boiler, which is over 6 inches in diameter, was broken in three places. The two forward boilers were ruined, one of them not having a single tube left in place. The forward part of the vessel, extending over the two forward compartments about 14 feet from the bow, was entirely crippled. The side was entirely crippled in the neighborhood of the forward bulkhead of the forward fire room, about 65 feet from the bow. The whole forward part of the vessel, including the two boilers, will have to be renewed. It was stated at the inquest that the steam pressure at the time of the accident was 160 pounds per square inch.

The *Lynx* had a large rent in the port bow and several plates were stove in on that side. The stem was bent around at an angle of nearly 90°, and a hole was knocked in the bottom under the forecastle and on the keel line. One boiler will have to be renewed. ("London Times" and other sources.)

The *Thrasher* was mentioned on page 173 of the February number, and the *Lynx*, on page 821 of Volume VII.

Panther.—This 30-knot torpedo boat destroyer, built by Messrs. Laird Bros., and mentioned on page 174 of the February number, has finished the official trials.

On July 8, the coal consumption trial was made, the mean speed for the six runs over the Skelmorlie mile being 30.47, and for the three hours, 30.17 knots; the mean number of revolutions per minute for the mile runs was 376.3, and for the three hours, 372.2.

On July 14, the speed trial was made in a heavy sea and stormy weather, the mean speed for the six mile runs being 30.52, and for the three hours, 30.16 knots. The steam pressure averaged about 219 pounds per square inch.

Cheerful.—This 30-knot torpedo boat destroyer, built by Messrs. Hawthorne, Leslie & Co., Newcastle-on-Tyne, and mentioned on page 622 of Volume VIII, was successfully launched on July 14. The *Mermaid*, a sister vessel, is building by the same firm. The principal data of these vessels are as follows.

The length is 210 feet; beam, 21 feet; depth, 12.5 feet; and displacement, 308 tons.

There are twin screw triple expansion engines, designed for 6,000 I.H.P. at full power, and four Thornycroft boilers with a working pressure of 250 pounds per square inch.

Violet.—This 30-knot destroyer, built by Messrs. Doxford & Sons, Sunderland, and mentioned on page 606 of the August number, made a three hours' trial on September 17. The mean speed for the six runs over the mile was 30.307 knots.

Osprey.—This 30-knot destroyer, built by the Fairfield Co., Govan, and mentioned on page 606 of the August number, completed the official trials in the first week in October.

The speed trial resulted in a mean speed of 31.1 knots at 402 revolutions per minute, for the six runs over the measured mile. The I.H.P. was 6,579, and the fastest mile was run at 31.5 knots.

The three hours' coal consumption trial gave the following mean results. Steam pressure in boilers, 248, and at engines, 241 pounds per square inch; vacuum, 22 inches; revolutions per

minute, 394; I.H.P., 6,544; speed, 30.6 knots; air pressure, 4.5 inches of water; and coal per I.H.P., 2.6 pounds per hour.

The contract I.H.P. was 6,000, and the speed, 30 knots.

30-Knot Destroyers.—Contracts have been let for five new vessels, the following firms receiving one each. The Fairfield Shipbuilding and Engineering Co., Govan; Palmer's Shipbuilding and Iron Co., Newcastle; Messrs. Wm. Doxford & Sons, Sunderland; Messrs. Laird Bros., Birkenhead; and Messrs. J. I. Thornycroft & Co., London.

The new vessels will be similar to those now building. The length will be 210.5 feet; beam, 21.5 feet; draught, 8.25 feet; corresponding displacement, 300 tons. The power of the engines will vary from 5,600 to 6,000 I.H.P. They will carry one 12-pounder and five 6-pounder rapid fire guns. The cost of these boats ranges from $235,000 to $250,000 each.

FRANCE.

Dupetit-Thouars.—This first class, armored, triple screw cruiser has been ordered to be laid down at Toulon. This vessel takes the place of the proposed larger cruiser C_3, described on page 175 of the February number. The plans of the new cruiser are by Naval Constructor Bertin. The following particulars are from "Le Yacht," Paris.

The length will be 452.8 feet; beam, at water line, 63.65 feet; beam, maximum, 1.97 feet above water line, 63.98 feet; mean draught, 22.96 feet; load displacement, 9,366 tons.

The armament will consist of two 7.64-inch guns in turrets, one forward and the other aft; eight 6.49-inch rapid fire guns in armored casemates, four having ahead, and four, astern fire; four 3.94-inch rapid fire guns on the deck above the 6.94-inch guns, two having ahead, and two, astern fire; sixteen 1.85-inch and six 1.46-inch rapid fire guns; and two submerged torpedo tubes. There will be six search lights.

The three engines will be of the vertical triple expansion type, and are designed to develop together 19,330 I.H.P. and give the vessel a speed of 21 knots. There will be twenty Normand boilers. The normal fuel supply, coal and liquid fuel, will be about

1,000 tons, giving a radius of action of 6,500 nautical miles at 10 knots. The maximum fuel supply will be 1,575 tons.

Admiral de Gueydon.—Another triple screw cruiser, similar to the above, will be built at Lorient, according to "Le Yacht," Paris.

Bruix.—This twin screw armored cruiser, the trials of which were given on page 177 of the February number, has been the cause recently of much comment and criticism on account of her breakdown. She was one of the vessels accompanying the President of France on his visit to Russia. Soon after leaving Dunkirk, and while steaming at about 14 knots, the P.I.P. piston rod broke and the lower cylinder head was carried away. The vessel returned to port and was relieved by the *Dupuy de Lôme*. The official inquiry found that the cause of the breaking of the rod was due to a hidden flaw in the material, and that no water had been carried over from the boilers.

Kersaint.—This steel sheathed cruiser, laid down at Rochefort in 1895, and described on page 191 of Volume VIII, was successfully launched on August 28.

The length is 225.2 feet; beam, 34.45 feet; draught, aft, 15.09 feet; and displacement, 1,223 tons.

The armament will consist of one 5.45-inch, five 3.94-inch and seven 1.46-inch rapid fire guns.

The I.H.P. of the vertical triple expansion engine will be 2,170, and the speed of the vessel, 15 knots. D'Allest boilers with small tubes will be installed.

The complement will consist of 7 officers and 94 men. The estimated cost of the vessel is $539,666.

Decidée.—This gunboat, to be built at Lorient on plans by Mr. Normand, was laid down on April 20. The following data are from "LeYacht," Paris.

The length is 184.7 feet; beam, 24.57 feet; draught, aft, 12.3 feet; displacement, 619 tons.

The armament will consist of two 3.94-inch, four 2.56-inch and four 1.46-inch rapid fire guns.

There will be one triple expansion engine, designed to develop 888 I.H.P. and give the vessel a speed of 13 knots. The theo-

retical steaming radius at this speed is 1,000 nautical miles. One Niclausse water tube boiler will be installed.

Torpedo Boats Nos. 201, 202 and **203.**—These boats were built by Mr. A. Normand at Havre, and are especially interesting on account of being fitted with the simple automatic feed-regulating, or, more properly speaking, feed-equalizing arrangement, recently patented by Mr. Normand. The following information is compiled from "Engineering," London.

These boats are 121.25 feet long on the water line and have a beam of 13 feet 7 inches; displacement on trial, 83 tons. There is one engine and two Normand boilers, the latter having a total grate surface of 45, and a heating surface of 2,120 square feet.

The full speed trials consisted of three runs on the measured mile, a two hours' run in open sea, and three more runs on the measured mile. No alteration in the opening of the steam valve and in the introduction of steam in the cylinders was allowed during the whole trial. The results, averaged for the three boats, were as follows. Displacement, 83 tons; I.H.P., 1,920; coal consumed per hour, 2,780; coal per I.H.P. per hour, 1.45 pounds; speed, mean for the two hours' run, 25.703 knots.

The weights on board, included in the 83 tons' displacement, and exclusive of chains, anchors, masts, boats, electric light, which were on board, were as follows, the boats being otherwise ready for sea: torpedo tubes, torpedoes and air compressor, artillery and ammunition, reserve water, crew and stores, 10.40, coal, 10.30, total, 20.70 tons.

The 10.30 tons of coal was the minimum to be carried according to contract. From the eight hours' consumption trials at 14 knots, it was found to be sufficient for steaming 1,090 miles at 14 knots (mean of the three boats).

The feed-regulating arrangement consists in connecting both boilers near the water level by a pipe with valves, so as to equalize the water level, even when the supply of feed and the production of steam are different in each boiler. The only other connection between the boilers is the steam pipe, the diameter of which is slightly increased (it is about the same as that of the steam collector to the engines), in order that the difference of pressure should be very small. Of course, the valves of the

pipes must always be fully opened when working normally with both boilers. In case of accident to one boiler, the valves can be shut either from below or from the deck. Even should the operation require several minutes, a very small fraction only of the water contained in the sound boiler would be lost, since the lowest connection between both boilers is situated near the water level.

During the full speed trials of these torpedo boats, no appreciable difference of level was found to exist in the boilers, as measured by a water level placed in the stokehold, so as to be independent of the alterations of trim due to the speed. On one of the boats, an official test of the feed-regulating arrangement was made as follows. Instead of feeding both boilers, as is usual, the feed was shut off from the forward boiler, the full amount being supplied to the after boiler; after one-half hour, the conditions were reversed, the whole feed being introduced into the forward boiler. In both cases the speed was 18 knots. The difference of height of water between both boilers, measured as before by an exterior water level, was found to be about one inch; it was naturally higher in the boiler receiving the feed.

The diameters of pipes necessary for attaining the above results are not large enough to cause any inconvenience, as may be seen by the following details. Diameter of steam pipe connecting the two boilers, $6\frac{1}{4}$ inches, of steam collector to the engines, $6\frac{1}{4}$ inches, and of pipe connecting both boilers near the water level, $3\frac{1}{8}$ inches. This last diameter is small enough to make no appreciable difference in the water level of each boiler during the pitching motions of the boat.

Du Chayla.—This protected cruiser, described on page 188 of Volume VIII, made a preliminary full power trial on September 23 off Cherbourg, but the result was not satisfactory. With the engines running at 150 revolutions per minute, the I.H.P. developed was only about 8,780, instead of 9,370, as designed. The machinery worked satisfactorily, but, to give the desired result, the propellers will probably be changed. In October, the first two official trials at 986 and 3,452 I.H.P. were made with good results.

Cassard.—This cruiser, a sister vessel of the *Du Chayla*, and mentioned on page 626 of Volume VIII, has been making the official trials, but the published results are very few. A preliminary trial in August gave a speed of 20.8 knots on the measured mile, with the engines running at 130 revolutions per minute. On September 8, the first official coal consumption trial at 984 I.H.P. was satisfactorily completed. The trial at 7,890 I.H.P. was also satisfactory.

Dunois.—This torpedo boat destroyer was described on page 190 of Volume VIII. She was laid down at Cherbourg on September 15, 1896, and launched on October 6, 1897. The following additional data are from "Le Yacht," Paris.

The length is 255.9 feet; beam, 27.88 feet; draught, aft, 12.73 feet; and displacement, 882 tons. No torpedo tubes will be fitted. The vessel will have two signal masts and two smoke pipes, and carry 135 tons of coal. The twin screw triple expansion engines are designed to develop about 6,900 I.H.P. and give the vessel a speed of 23 knots.

The complement will consist of 8 officers and 120 men.

A sister vessel, the *La Hire*, has not yet been launched.

Torpedo Boats Nos. 230, 231 and 232.—The contract for building these three torpedo boats has been given to the Chantiers de la Gironde at Rochefort, which is building six other boats of the same class.

The length will be 123 feet; beam, 13.32 feet; draught, aft, 8.53 feet (?); and displacement, 84.94 tons. The armament will consist of two 1.46-inch rapid fire guns and two torpedo tubes.

The single screw engine is designed to develop 1,479 I.H.P. and give each vessel a speed of 24 knots. The coal capacity will be about ten tons, and the complement, 2 officers and 21 men. The cost of each boat will be about $77,700.

GERMANY.

Aegir.—This fourth class battleship, described on page 604 of Volume VII, has completed her trials. The principal data of the vessel are repeated here.

Length on water line, 236.2 feet; beam, 50.52 feet; depth, 35.56 feet; draught, mean, 17.39 feet; displacement, 3,542 tons.

The engines are twin screw triple expansion, with cylinders 26, 40 and 63 inches in diameter, and 29.5 inches stroke, and are designed for 2,400 I.H.P. each with 175 pounds boiler pressure. The propellers are 11.5 feet diameter and 12 feet pitch. Steam is furnished by eight Thornycroft boilers of the old type, having a combined grate surface of 274, and a heating surface of 16,150 square feet.

The following results of the trials are from the "Marine Rundschau," Berlin.

Duration of trial, hours	6	24	4	24
Kind of trial	Forced draft.	Endurance.	Forced draft.	Service speed.
Number of boilers used	8	8	4	8
I.H.P.	4948	3318	2056	1111
Cut-off, H.P. cylinder	.66	.5	.5	.54
Air pressure under grates, inches	1.3	.49	.....	0
Coal per square foot grate, pounds	Not determined.	22.46	39.86	10.48
I.H.P. per hour, pounds		1.85	2.66	2.59

The weight of the boiler installation of this vessel is given as 192.53 tons.

Kaiser Wilhelm II.—This first class, triple screw battleship, a sister vessel of the *Kaiser Friedrich III*, mentioned on page 179 of the February number, was successfully launched at the dockyard at Wilhelmshaven on September 14. The keel was laid on October 26, 1896, and the vessel is said to have been ready for launching on July 25, 1897, but was delayed for convenience.

Prinz Bismarck.—This first class armored triple screw cruiser, described on page 827 of Volume VII and page 406 of Volume VIII, was successfully launched at the dockyard at Kiel on September 25. This cruiser replaces the *Leipzig*. The data so far available are given below.

The length between perpendiculars is 393.7 feet; beam, extreme, 66.93 feet; mean load draught, 25.91 feet; displacement, 10,482 tons.

The side armor, extending completely around the vessel, is of Krupp steel, 7.55 feet wide, and varies in thickness from 7.87 to 3.94 inches. The protective deck, from 1.18 to 1.97 inches thick, is of nickel steel and joins the belt armor at its upper edge.

Forward and aft there is an additional nickel steel, curved protective deck. There is a splinter deck, .79 inch thick, over the engine and boiler compartments. There are two military masts with fighting tops. The conning tower is 3.94 and 7.87 inches thick.

The armament will consist of two 9.45-inch, twelve 5.9-inch, and ten 3.46-inch rapid fire guns; eighteen machine guns; and six torpedo tubes, of which the stern tube is under water.

The two 9.45-inch guns will be in turrets with 7.87 inches of armor; six of the 5.9-inch rapid fire guns will be in armored casemates, 3.94 inches thick, and the other six, in revolving turrets with 3.94 inches of armor; the ten 3.46-inch rapid fire guns will be protected by shields.

The three, four-cylinder, vertical, triple expansion engines are designed to develop 13,315 I.H.P. and to give the vessel a speed of from 18.5 to 19 knots. Water tube boilers will be used for one-third of the power, and cylindrical boilers for the remaining two-thirds.

The coal supply at normal draught will be about 985 tons, and the complement, 565 officers and men.

Freya, Hertha, Victoria Louise, M and N.—These triple screw cruisers were described or mentioned on page 610 of the August number, pages 427 and 426 of the May number, and page 631 of Volume VIII. The following information regarding the boilers is from the "Marine Rundschau," Berlin.

	Freya.	*Hertha.*	*Victoria Louise.*	*M.*
Number and kind of boilers	12 Niclausse.	18 Belleville.	12 Dürr.	12 Dürr.
of fire rooms	4 (?)	6	6	6
Working pressure in boilers	185	256	185	185
Total grate surface, square feet	807.3	794.4	674.25	599.6
heating surface, square feet	26,437	23,832	27,825	25,177
Ratio H.S. to G.S	32.75	30	41.27	41.99
Contract I.H.P., full power	9,863	9,863	9,863	9,863
Coal to be burned per square foot G.S. at above power	27.3	27.65*	32.7	36.76
Weight of boilers, clothing, brickwork, water, smoke pipes, uptakes, pumps and pipes with water, and blowers complete, tons	398.6†	409.92	391.7†	398.6†
Weight of above per square foot G.S., pounds	1,106	1,156	1,301	1,489
Weight of above per I.H.P., pounds	90.53	93.1	88.96	90.53
I.H.P. per ton of boiler weights	24.74	24.06	25.18	24.74

* Estimated. †Contract.

Cruiser *N*, a sister vessel of the *Hertha*, will have eighteen Belleville boilers which will be, probably, duplicates of those of the *Hertha*.

Evaporative tests were made at the Vulcan Co.'s works of a Belleville boiler, the dimensions of which are, in general, the same as those of the boilers for the *Hertha*. The principal dimensions and a description of the boiler tested are given below.

Heating surface, water, square feet	645.9
total, square feet	1,265.
Grate surface, square feet	42.
Height of top of smoke pipe above grate, feet	40.35
Diameter of smoke pipe, feet	2.13
Maximum permissible working pressure, pounds per square inch	256.
Grate surface in use on first and third trials, square feet	20.99
second trial, square feet	24.48
Weight of boiler with clothing, shell, brickwork, and water to normal level, tons	15.34

The boiler was composed of ten double rows of water tubes, all galvanized on the outside, the two lower rows being of the Serve pattern, and the eight upper ones, plain seamless-drawn. The external diameter of all tubes was 3.86 inches. Baffle plates were fitted in several places. The boiler was tested in a house specially arranged for such trials and which could be put under an air pressure.

Three six-hour tests were made, with a coal consumption of 16.38, 20.48 and 27.65 pounds of coal per square foot of grate, respectively. The consumption of 16.38 pounds corresponds to the contract requirement for the maximum endurance tests of the boilers for the *Hertha* and cruiser *N*, and that of 27.65 pounds, to the estimated quantity necessary to develop the full power of 9,863 I.H.P. on those cruisers.

The coal was fired in equal quantities at regular intervals. The feed water was measured, and the temperature of the gases of combustion read from a pyrometer placed over the upper row of tubes. Air could be admitted under the grate through the ash pit opening, and through holes in the side and back walls of the ash pit; over the grate, it came through the holes in the furnace door. The regular Belleville air compressor, to force air

over the grate, was not fitted. A Chandler blower put the boiler room under air pressure.

The principal results of the tests are as follows.

	Feb. 22, '97.	Feb. 23, '97.	Feb. 24, '97.
Test No.	1	2	3
Coal burned per square foot of grate per hour	20.48	27.65	16.38
Steam pressure, pounds per square inch	250	250	253
Temperature of feed water, Fahrenheit	36	37.4	35.6
outside air, Fahrenheit	37.4	37.4	39.2
in boiler room, Fahrenheit	98.6	109	103.3
of gases of combustion, Fahrenheit	674.6	762.8	674.6
Air pressure, inch of water	.256*	.323	.307
Pounds of water evaporated per hour	6,202	7,853	5,368
from feed water at 32° into steam at 212°, per hour per pound of coal	7.5† 7.8*	7.07	8.3

* During the admission of air over the grate. † Without admission of air over grate.

S-26.—This second class torpedo boat capsized on September 26 off Cuxshaven. The captain and seven men were drowned; nine men were saved by the torpedo boat *S-27* which was accompanying No. 26.

The length of the boat was 128 feet; beam, 16 feet; draught, 6 feet; displacement, 85 tons; I.H.P., 1,000.

ITALY.

Emmanuele Filiberto.—This battleship, described on page 196 of Volume VIII, was successfully launched at Castellamare on September 30.

Varese.—This twin screw armored cruiser, laid down on June 9, 1896, and built by the Messrs. Orlando Bros., Leghorn, was successfully launched on July 25, 1897. The original *Varese* was described on page 605 of Volume VIII. The general data of the second vessel are repeated here.

The length is 328.1 feet; beam, 59.7 feet; draught, about 23.25 feet; displacement at load draught, 6,732 tons. The engines are to develop about 13,000 I.H.P. under forced draft and give the vessel a speed of 20 knots.

Garibaldi.—This twin screw armored cruiser, built by Messrs. G. Ansaldo & Co. at Sestri Ponente for the Italian Government, to replace the vessel which was sold by the builders to the

Argentine Government, was successfully launched on September 26. A description of the original *Garibaldi* was given on page 605 of Volume VIII. The general data of the second vessel are given above under *Varese*. The total cost of the vessel is estimated at $2,730,000.

JAPAN.

Yashima.—This first class battleship, described on page 414 of Volume VIII, completed her official speed, torpedo and turning trials in July. The following results of the trials and details of the machinery are from "Engineering," London. The principal features of the vessel are here repeated.

Length over all, 412 feet, on water line, 400 feet; beam, 73.5 feet; draught, mean normal, 26.25 feet; corresponding displacement, 12,400 tons. Designed I.H.P. under natural draft, 10,000, corresponding speed, 16.75 knots; under forced draft, 1.5 inches of air pressure, 13,500, corresponding speed, 18.25 knots. There is a partial belt of harveyized armor, 18 inches thick in the middle of the vessel and 14 inches at the ends. The armament consists of four 12-inch guns in two barbettes; ten 6-inch and twenty-four smaller rapid fire guns; and five 18-inch torpedo tubes, four in broadside and submerged. This vessel and her sister vessel, the *Fuji*, are the only completed warships, other than British, having submerged tubes. These tubes have been designed by the builders of the vessel, Sir W. G. Armstrong, Whitworth & Co., and differ entirely from those adopted in the British Navy. The required propulsive power is obtained from cordite, although steam and compressed air may be used.

The twin screw engines are of the triple expansion, vertical, direct-acting, three-crank type, with cylinders, 40, 59 and 88 inches in diameter, the stroke being 45 inches. The full power under forced draft (13,500 I.H.P.) was to be obtained when the engines were making 120 revolutions per minute, and with a steam pressure of 155 pounds per square inch. The cylinders are carried on castings of the usual type at the back, and have turned columns in front, each engine standing independently, the cylinders being separate castings. The whole is carried on a steel framing attached to the ship. The cylinders are jacketed,

the required pressures being regulated by reducing valves, the drains being hand-regulated. The cylinder covers and the pistons are of cast steel. All cylinders have slide valves with balance pistons on top and equilibrium rings on the back. The high pressure valve is double-ported, while the intermediate and low pressure valves are triple-ported. The valve gear is the ordinary link motion, fitted with solid link and sector. The valve spindle is screwed into a square sector block, means being provided for adjustment to take up wear. The vertical motion is controlled by a solid casting which projects downwards from the cylinder and acts as a guide. The eccentric rods are attached to the straps by bolts. The reversing engine is placed on the front of the engine. Means are provided for varying the cut off in the different cylinders independently, by means of levers fitted with adjustable screws acting on the drag link.

The crankshafts, of hollow-forged steel, are each in three parts, the cranks being placed at equal angles. The air pumps are carried on the back frame casting of each low pressure engine, and are worked directly from the piston by means of a rod, which passes through a stuffing box in the bottom cover. The stroke of the air pump bucket is, therefore, the same as that of the engine itself. The arrangement is generally adopted by Messrs. Humphrys, Tennant and Co., for this class of engine; and though it was common with the old horizontal engines of warships, it is quite unusual with vertical engines. It makes, however, a very snug arrangement and takes up less room, allowing a freer passage at the back than when side levers are used. It also saves weight and reduces the working parts. That it is an efficient arrangement is proved by the excellent vacuum this firm gets on its engine trials. The pump has foot and bucket valves and head valves as usual. All rubbing surfaces are of white metal, excepting the top end of the connecting rod.

There is a rectangular surface condenser for each set of engines. These are placed behind the low pressure cylinders, and contain collectively 13,500 square feet of cooling surface. There are also two auxiliary condensers, one in each engine room, cylindrical in form, and each with its separate air and circulating

pump. The larger steam pipes are of steel, and are either welded or solid-drawn.

The ten boilers are of the usual single-ended return tube type, with four furnaces, and are placed back to back in four separate water tight compartments, three in each of the two forward compartments and four in the two after ones. The furnaces are athwartship, as in recent British ships. Each boiler is 9 feet 7¼ inches long and 15.25 feet in diameter. Each pair of furnaces (Purves' ribbed) has a combustion chamber in common. The tube ends are fitted with Humphrys' patent tube connection, which has given admirable results, and has been in use since it was first practically tried on the *Royal Sovereign*.

Eight blowers will supply the forced draft, which is on the closed fire room system. There is an auxiliary boiler on the deck above the protective deck. It is 9 feet 5 inches long and 10.25 feet in diameter.

The propellers are of gun metal and are three-bladed.

The first official trial was made off the mouth of the Tyne on July 13, with forced draft (1½ inches of pressure), and was of four hours' duration. The mean speed for the trial was 19.227 knots, and for four runs over the measured mile, 19.46 knots; air pressure, 1½ inches; mean I.H.P., 14,075. There was an abundance of steam.

Subsequently, the six hours' natural draft trial was made, the mean speed for four runs over the mile being 17.73, and for the six hours, 17.26 knots; mean I.H.P. for whole trial, 9,570.

At the end of this trial, turning trials were made at full speed. With the rudder hard over and both engines going ahead, the diameter of the turning circle was 180 yards; with 10 degrees of helm, the diameter was about 420 yards. These results are due to the cutting away of the after dead wood for a considerable length of the vessel, and putting in an exceptionally large balanced rudder low down. This system of construction was designed by Mr. Watts and is adopted in all Elswick-built cruisers planned by him.

Trials of the torpedo tubes, when steaming at 16 knots and at

lower speeds, were made on July 14. Although these were very satisfactory, it was determined to subject the tubes to a more exhaustive trial, and a series of discharges were made up to 17.5 knots. The first trials took place on August 27, when a number of rounds were fired with the ship stationary, and at 15, 16 and 17 knots, the results leading to some adjustments being made. Further trials were carried out on September 15, when a number of rounds was fired with the ship stationary and at various speeds up to and including 17.5 knots, with most satisfactory results. In each case the cordite impulse was used. The torpedo tubes gave every satisfaction on all occasions, and, as now 150 rounds have been fired from this apparatus, it may safely be said that it has completed its experimental stage. With these submerged tubes, even at a speed of 17 knots, the deflection of the torpedo is so little that it may almost be neglected.

———.—This first class battleship is building by Sir W. G. Armstrong, Whitworth & Co., Newcastle, and will be similar to the battleship building by the Clydebank Co., mentioned on page 612 of the August number.

———.—The contract for this armored cruiser has been let to the Société de la Loire, St. Nazaire, according to "Le Yacht," Paris, from which the following particulars are taken.

The length between perpendiculars will be 445.87 feet; beam at water line, 59.84 feet; depth, 40.27 feet; mean load draught, 25.06 feet; load displacement, 9,287.25 tons. The armor belt will be 6.3 inches thick.

The armament will consist of four 7.87-inch guns in two turrets; eight 5.9-inch rapid fire guns in armored casemates; four 5.9-inch rapid fire guns protected by shields; twelve 2.95-inch and twelve 1.85-inch rapid fire guns; several machine guns; and five torpedo tubes, four under water, and one forward above water. There will be two military masts.

The twin screw triple expansion engines will be built by the same company at their St. Denis yard, and are designed to develop 16,767 I.H.P. and give the vessel a speed of 20 knots. The boilers will be arranged in three groups.

PORTUGAL.

Dom Juan de Castro and **Infante Dom Henrique.**—These are the names of the two cruisers building in France and described on page 183 of the February number.

RUSSIA.

Rossija.—This triple screw cruiser, referred to on page 433 of the May number, made full speed official trials on July 18, with two engines and with the center engine alone. The following data are from Russian sources in the "Marine Rundschau," Berlin.

First the two wing engines were run for six hours at full power, including ten runs over a measured base of four miles. The mean draught of the vessel was 25.91 feet forward, and 27.56 feet aft; the corresponding displacement was 11,938 tons. The mean speed was 19.74 knots; steam pressure, 141 pounds per square inch; revolutions per minute, 83.5. The I.H.P., from seven sets of cards, was as follows. Starboard engine (with a mean number of revolutions of 83.5 per minute), H.P. cylinder, 2,486, I.P., 2,514, L.P., 2,591, collective, 7,591; port engine (mean revolutions 83.1), H.P. cylinder, 2,541, I.P., 2,539, L.P., 2,638, collective, 7,718. Total I.H.P., 15,308, or 1,008 over the contract requirement. The maximum performance, from one set of cards, was for the starboard engine, steam, 153.6; revolutions, 84; I.H.P., 8,072; and for the port engine, steam, 150.8; revolutions, 85; I.H.P., 8,208. Total I.H.P., 16,280, with a speed of 20.06 knots. The wing propellers are four-bladed, 20.01 feet in diameter, and have a pitch of 27.56 feet. The engines worked well and made 3.5 revolutions per minute more than the contract requirement.

After the above trial, the center engine was run alone for two hours at full power, including three runs over the same base. The mean speed was 9.92 knots; steam pressure, 141 pounds per square inch; revolutions per minute, 99.8; I.H.P., from five sets of cards, 2,864. The engine worked very regularly. The Bevis propeller on the center shaft had a pitch of 15.09 feet.

It may be recalled that the contract requirement was 14.301 I.H.P. for both wing engines, and 2,466 I.H.P. for the center engine.

Aurora, Diana and **Pallada.**—The last two of these triple screw cruisers were partially described on page 188 of the February number. As these cruisers are sister vessels, the following details of the *Aurora*, taken from Russian sources by the "Marine Rundschau," Berlin, will apply to the other two. The displacement and I.H.P., previously given, are in metric units, as will be noticed by the figures given below.

The length between perpendiculars will be 405.81 feet; beam, 55.12 feet; draught, 21 feet; displacement, 6,525 tons.

The three triple expansion engines, each of which is to develop 3,817 I.H.P. (or a total of 11,451 I.H.P.), will have cylinders 37.4, 66.9 and 74.8 inches in diameter, the stroke being 31.89 inches. The cylinders, valve chests and covers will be of cast iron. The H.P. and I.P. valves will be of the piston type and made of cast iron. The ordinary double eccentric valve gear, with cut-off arrangement, will be fitted. The three main condensers will have a total cooling surface of 20,132 square feet, and the auxiliary condenser, 4,060 square feet. The condenser tubes will be of brass, not tinned. The shafting will be of hollow steel. The three-bladed propellers will be of gun metal, and have a diameter of about 13 feet. The main circulating pumps are to be capable of discharging 787 tons of water per hour, with a steam pressure of 90 pounds per square inch, and running 280 revolutions per minute. The feed tank will have a capacity of 25.6 tons, and tanks in the double bottom for make-up feed, about 114.2 tons. The evaporators are to supply 59 tons of fresh water per day for the boilers.

There will be twenty-four Belleville boilers in three groups, the total grate surface being about 1,162, and the heating surface, 36,060 square feet; ratio of H.S. to G.S., 31.03 to 1. The working pressure will be 235 pounds per square inch. There will be three smoke pipes, about 89 feet high above the grates. Twelve feed pumps will be supplied with the boilers.

Khrabry.—This twin screw gunboat, partially described on page 200 of Volume VIII, had her full power trial on September 17, although launched very nearly two years ago. The trial lasted six hours, the I.H.P. developed being about 2,200, or ten

per cent. more than the contract power, and the coal per I.H.P., 1.68 pounds per hour. On the return from the trial, a tube was taken out of one boiler and replaced by a new one, the whole operation taking, it is said, 35 minutes. The following particulars of the Niclausse boilers are from the "Rivista Marittima," Rome.

There are eight Niclausse boilers divided into four groups, the total grate surface being 223.9, and the heating surface, 6,786 square feet; ratio H.S. to G.S., 30.1 to 1. The horizontal projection of the boilers covers a surface 32.08 feet long by 11.81 feet wide, or 378.86 square feet. The height of the boilers is 10.32 feet.

The weight of all boilers, including brick work, clothing, valves, &c., but not including the smoke pipe, is 68.44 tons, and with water and uptakes, 84.85 tons; weight of spare parts for boilers and tools, 10.71 tons; weight of feed pumps, blowers, separators and piping, 9.96 tons; total weight of boiler installation, ready for steaming, 105.52 tons.

There are two Thirion feed pumps for each group of boilers, or eight pumps in all. Two pumps only are used ordinarily, the others being kept in reserve. There are two blowers for each group. Each boiler has 9 elements of 21 tubes each, the tubes being 3.23 inches in diameter and 4.92 feet long.

Gilyak.—This twin screw gunboat, built at the Admiralty yard at St. Petersburg, was successfully launched on October 5.

The length over all is 207 feet; beam, 37 feet; displacement, 963 tons.

The armament will consist of one 4.7-inch, five 2.95-inch and four 1.86-inch rapid fire guns; two machine guns; and one torpedo tube in the bow.

The triple expansion engines, designed to develop about 1,000 I.H.P., were built by Messrs. Creighton, Abo, Finland.

SPAIN.

Isabel la Catolica.—This cruiser, of 2,953 tons' displacement, will be laid down at Cadiz, according to "LeYacht," Paris. The cost will be defrayed by the contributions of Spanish colonists in South America.

Rio de la Plata.—The following additional data of this steel sheathed cruiser, described on page 617 of the August number, are from "LeYacht," Paris.

The length between perpendiculars will be 246 feet; beam, 35.42 feet; depth, 22.63 feet; mean draught, 14.27 feet; load displacement, 1,746.9 tons. The engines will be of the vertical, three-cylinder, triple expansion type, and the boilers, of the Normand-Sigaudy type.

There will be two dynamos of 200 ampères and 100 volts for lighting purposes and for the hoisting of ammunition for the two largest sizes of guns.

Don Alvaro de Bazan.—This torpedo gunboat, built by Messrs. Vila & Co., Ferrol, was launched on August 14. She is practically a sister vessel of the *Marques de la Victoria*, described on page 437 of the May number. The following data of this vessel are from the "Revista General de Marina," Madrid.

Length between perpendiculars, 232.9 feet; beam, 26.73 feet; depth, 14.46 feet; draught, forward, 6.56, aft, 10.92, mean, 8.74 feet; corresponding displacement, 810 tons. There are 28 water tight compartments.

The armament will consist of two 4.7-inch rapid fire guns, system Loma; four 1.65-inch Nordenfeldt guns; two Hotchkiss machine guns; and three torpedo tubes, one in the bow and two in broadside.

The twin screw triple expansion engines are designed to develop 2,466 I.H.P. under natural draft, and 3,452 under forced draft, the respective speeds of vessel being 17 and 19.25 knots. There are four locomotive boilers with a working pressure of 142 pounds per square inch. They are protected by coal bunkers at the sides, on top and forward and abaft of the boilers. The engines are similarly protected, except that there is a chrome steel bulkhead, .98 inch thick, at the after end, instead of a coal bunker.

There are two dynamos of 100 amperes at 70 volts. The complement will consist of 7 officers and 102 men. The total cost of the vessel complete is estimated at about $400,000.

Pluton.—This torpedo boat destroyer, mentioned on page 438 of the May number, was launched in July.

MERCHANT STEAMERS.

Kaiser Friedrich.—This express steamer, described on page 620 of the August number, was successfully launched by Mr. Schichau on October 5. The following additional data are from "Engineering," London. The vessel has been built to comply with the requirements for an auxiliary cruiser. She has a forecastle 120 feet in length, and a midship erection, which together with the poop extends to 444 feet. Amidships is a roomy deck house 300 feet in length, and over the promenade and deck house is a deck the whole width of the ship, thus forming a permanent awning for the first class promenade deck. The whole midship portion of the ship is reserved for the first, and the after part, for the second cabin passengers. Nearly all the first class sleeping cabins, and most of the second class, are in the deck structures above the upper deck, where the ports can be kept open in almost any weather. This arrangement of berthing ensures the most important advantage that at night time and in foggy weather all the necessary openings in the bulkheads below deck can be kept closed, without materially interfering with the free movements of the passengers. For the first class, there are about 180 sleeping cabins, to hold together about 350 passengers, most of these cabins consisting of "Pullman" rooms. The first class dining saloon is on the main deck amidships.

The crew will consist of 400 men, 180 being for the engines alone. The whole of the latter *personnel* will be berthed in the immediate neighborhood of the engine rooms. Great care has been bestowed upon the comfort of these men; the stokers and coal trimmers will have a mess room to themselves. The greater part of an awning deck has been set apart for their use, where, after their hard labor below, they can enjoy the fresh sea breeze in any weather. The officers have comfortable quarters on the promenade deck.

To ensure a better trim of the ship, and for the purpose of avoiding vibration as much as possible, the engines have been placed, not in the after part of the ship, as has hitherto been the general custom on ships of this class, but amidships, an innovation adopted for the first time in the merchant service. Abaft the engines there is a boiler compartment, with three of the nine main boilers. Howden's system of forced draft is fitted. The ship has three funnels, equidistant from each other, and two masts, and, having very graceful lines, she will have the appearance of a beautiful yacht.

Kaiser Wilhelm der Grosse.—This express steamer, built by the Vulcan Works, Stettin, for the North German Lloyd Steamship Co., was referred to on page 619 of the August number. For the following additional particulars of the vessel, the JOURNAL is indebted to the courtesy of Mr. Thomas H. Barrett, U. S. Local Inspector of Steam Vessels at New York.

The gross tonnage of the vessel is 14,349.19, and the net tonnage, 5,521.13 tons. Bilge keels are fitted. She is allowed to carry 558 first class, 338 second class and 786 steerage passengers, besides her complement of 461 officers and men. Of this complement, there are 17 engineers, 18 oilers, 90 firemen and 75 coal passers, or a total of 200. There are eighteen metallic life boats and six Chambers' life rafts.

The twin screw triple expansion engines have cylinders 52, 89.81 and (2) 96.5 inches in diameter, the stroke, as given before, being 68.9 inches.

Each of the fourteen boilers is 16 feet 11.2 inches in diameter. The twelve double-ended boilers are 20 feet 5.7 inches, and the two single-ended boilers, 11 feet 6.7 inches long. The shell plates are $1\frac{7}{16}$ inches thick, with double butt straps and triple-riveted longitudinal seams, and double and triple-riveted circumferential seams. Each double-ended boiler has 868, and each single-ended boiler, 432 3.25-inch tubes, all 9 feet 9.2 inches long. The total number of furnaces is 104, incorrectly printed as 108 in the August JOURNAL. The grates are 6 feet long and 46 inches wide, the total grate surface being 2,392 square feet. The working pressure is 185 pounds per square inch. The usual

fusible plug is fitted in the top of one of the combustion chambers in each boiler. On each double-ended boiler there are six, and on each single-ended boiler, three $4\frac{1}{8}$-inch safety valves. There are eight independent duplex feed pumps, four of the Blake, and four of the Weir type. The Blake pumps are $7\frac{3}{4}$ inches in diameter and have a stroke of 12 inches, and the Weir pumps, 13 inches in diameter with a stroke of 26 inches. There are eight Blake duplex bilge pumps, 12 inches in diameter and a stroke of 16 inches.

On her first trip to New York, where she arrived on September 26, this vessel made the fastest time to date from Southampton, and also made the fastest time on her return voyage. She also made the greatest daily record that has been made.

The distance between the Needles and Sandy Hook, 3,049 miles by the log, was made in 5 days 22 hours 45 minutes. The American liner *St. Paul* had made the trip in August, 1896, in 6 days and 31 minutes. The daily runs of the *Kaiser Wilhelm* were 208, 531, 495, 512, 554, 564 and 186 nautical miles. The run of 564 miles is better by 2 miles than the best daily run made so far, that of the Cunard steamer *Lucania*. The run to Southampton, 2,962 nautical miles, was made in 5 days 15 hours 10 minutes, exceeding the best Eastward run made so far, that of the *Fürst Bismarck* of the Hamburg-American Line.

Königin Luise.—This twin screw freight steamer of the North German Lloyd Steamship Company, built by the Vulcan Works, Stettin, was partially described on page 861 of Volume VIII. She is a sister vessel of the *Friedrich der Grosse*, described on page 441 of the May number. For the following additional particulars, the JOURNAL is indebted to the courtesy of Mr. Thomas H. Barrett, U. S. Local Inspector of Steam Vessels at New York.

The gross tonnage of the vessel is 10,566.25, and the net tonnage, 6,754.56 tons. The steel hull is divided by twelve water tight bulkheads. The draught is 27 feet. She has accommodations for and is allowed to carry 205 first class, 78 second class and 640 steerage passengers, besides her complement of 180 officers and men. There are fourteen metallic life boats and six Chambers' life rafts.

The twin screw quadruple expansion engines have cylinders 25¼, 38¼, 52⅜ and 75½ inches in diameter, the stroke being 55⅛ inches. The engines run usually at 75 revolutions per minute.

There are seven main and one auxiliary boilers, all cylindrical and made of steel. Of the main boilers, five are double-ended, each 19 feet long, and two, single-ended, each 10 feet 8 inches long, the diameter of all being 13 feet 8¼ inches. The double-ended boilers have four, and the single-ended, two furnaces each, the grates being 6 feet 3 inches long and 4 feet wide. The total grate surface of the main boilers is 600 square feet, and the allowed steam pressure, 220 pounds per square inch. The shell plates are 1½ inches thick, longitudinal seams being double butt-strapped and triple-riveted, and the circumferential seams triple-riveted, the rivets being 1½ inches in diameter. The total number of 3-inch tubes in the main boilers is 3,840, and their length, 7 feet 4½ inches. The usual fusible plugs are fitted in the tops of two of the combustion chambers in each boiler. On each double-ended boiler there are four, and on each single-ended boiler, two 3⅝-inch safety valves.

There are four feed pumps worked by the main engines, four independent Weir and two auxiliary duplex feed pumps. The engine pumps are 4⅜ inches in diameter and have a stroke of 23⅝ inches, the Weir pumps, 8 inches in diameter with a stroke of 21 inches, and the duplex pumps, 5⅞ inches in diameter with a stroke 17¾ inches. There are, besides the two main circulating pumps, which have a suction to the bilge, five bilge pumps, two worked by the main engines, and three, independent; the diameter and stroke of the engine pumps are 5½ and 23⅝, and of the others, 5⅞ and 17¾ inches, respectively. There is besides a bilge ejector. There are three duplex fire pumps, of the same size as the independent bilge pumps.

The auxiliary boiler on the main deck is 7 feet 10½ inches long and 7 feet 2½ inches in diameter, and has one furnace, 5 feet 9¼ inches long and 36 inches in diameter, the grate surface being 17.31 square feet. This boiler has two $2\frac{9}{16}$-inch safety valves, and is allowed a working pressure of 88 pounds per square inch. The shell is $\frac{7}{16}$ inch thick and all shell seams are double-riveted.

Barbarossa.—This twin screw steamer of the North German Lloyd Steamship Company, built by Messrs. Blohm & Voss, Hamburg, some particulars of which were given on page 861 of Volume VIII, arrived at New York on her first voyage in June. For the following particulars of the vessel and her machinery, the JOURNAL is indebted to Mr. Thos. H. Barrett, U. S. Local Inspector of Steam Vessels at New York.

The gross tonnage of the vessel is 10,769, and the net tonnage, 6,385 tons. The draught is 27 feet. The hull is of steel, and is divided by twelve water tight bulkheads. She is allowed to carry 202 first and 83 second class, and 678 steerage passengers. The complement of officers and men is 97. There are fourteen metallic life boats and six Chambers' life rafts.

The twin screw quadruple expansion engines have cylinders 25.25, 37, 54.375 and 77.5 inches in diameter, the stroke being 54 inches.

There are seven cylindrical steel boilers, each 13 feet 4.5 inches in diameter. Five of these are double-ended, each 20 feet $1\frac{7}{8}$ inches long, and two, single-ended, each 10 feet long. The shell plates are 1.5 inches thick, all seams being treble-riveted with 1.5-inch rivets. There are thirty-six furnaces in all, the length of each grate being 6.5 feet, and the width, 3 feet. The total grate surface is 702 square feet. The total number of boiler tubes is 3,982, of which 3,140 are 3.5, and 842, 3 inches in diameter. The length of the tubes in the double-ended boilers is 7 feet 10 inches, and in the single-ended, 7 feet $\frac{7}{8}$ inch. In the crown of the center combustion chamber in each boiler there is a fusible plug. The allowed working pressure is 218 pounds per square inch. On each of the double-ended boilers there are three $4\frac{1}{2}$-inch, and on each single-ended boiler, two $3\frac{5}{8}$-inch safety valves. The feed pipes between the boilers are $2\frac{7}{8}$ inches, and the blow-off pipes, 1.5 inches in diameter.

There are seven feed pumps, four worked by the main engines, and three auxiliary pumps. The main engine feed pumps are 4 inches in diameter and have a stroke of 26.75 inches; the auxiliary pumps are 9, 6.5 and 8.5 inches in diameter, with a stroke of 21, 10 and $9\frac{7}{8}$ inches, respectively. There are four $4\frac{1}{2}$-inch

bilge pumps worked by the main engines, and three, independent, the stroke of the engine pumps being 26.75 inches. There are two bilge ejectors, and three double-acting fire pumps.

The auxiliary boiler on the main deck is of the cross tube type, and is allowed a working pressure of 80 pounds per square inch. It has one furnace, and a grate surface of 15.32 square feet.

Bremen.—This twin screw freight steamer, built by Mr. Schichau for the North German Lloyd Steamship Co., and referred to on page 201 of the February number, made the official trials in May, and has been making regular trips since. The following data of the vessel were kindly sent to the JOURNAL by Mr. Thos. H. Barrett, U. S. Local Inspector of Steam Vessels at New York. The data of the performances of the vessel are compiled from various German sources, and the description of the electric cranes, from the "Marine Review," Cleveland.

The registered tonnage is 10,552.37, and the net tonnage, 6,723.6 tons; 1807 tons of coal can be carried. The steel hull is divided by twelve water tight bulkheads, and has a double bottom throughout its length. There are two smoke pipes and two pole masts. The vessel is allowed to carry 200 first class, 80 second class and 366 steerage passengers.

The twin screw quadruple expansion engines have cylinders $27\frac{9}{16}$, $40\frac{15}{16}$, $59\frac{1}{16}$ and $83\frac{1}{2}$ inches in diameter, the stroke being $53\frac{1}{8}$ inches.

There are five main and one auxiliary boilers, all cylindrical and made of steel. Of the main boilers, three are double-ended, each 19.5 feet long, and two, single-ended, each 10 feet $\frac{3}{4}$ inch long, the diameter of all being 15 feet $\frac{1}{4}$ inch. The double-ended boilers have six, and the single-ended, three furnaces each, the grates being 5 feet 8 inches long and 3.25 feet wide. The total grate surface of the main boilers is 442 square feet, and the allowed steam pressure, 220 pounds per square inch. The shell plates are $1\frac{5}{8}$ inches thick, longitudinal seams being double butt-strapped and triple-riveted, and the circumferential seams, triple-riveted, the rivets being $1\frac{5}{8}$ inches in diameter. The total number of $2\frac{1}{2}$-inch tubes in the main boilers is 4,512, and their length, 6 feet 10 inches.

On each double-ended boiler there are four, and on each single-ended boiler, two 3¾-inch safety valves. There are eleven feed pumps, four worked by the main engines, four Weir and three Worthington duplex. The main engine feed pumps are 5.5 inches in diameter and have a stroke of 18.5 inches; the Weir pumps, 8.5 inches in diameter with a stroke of 24 inches; and the Worthington duplex pumps, 8¾ inches in diameter with a stroke of 13¾ inches. There are eight bilge pumps, four worked by the main engines, 5 inches in diameter and a stroke of 18½ inches, and four Worthington duplex, of the same size as the feed pumps.

The auxiliary boiler on the main deck is single-ended, 6.5 feet in diameter and 7.25 feet long, and has one furnace. The grate is 34 inches wide and 4 feet long, the grate surface being 11.3 square feet. The shell plates are of ½-inch steel. There are 120 2½-inch tubes, all 4 feet 8 inches long. Two 2-inch safety valves are fitted, the working pressure being 90 pounds per square inch. There are two feed pumps for this boiler, each 3 inches in diameter with a stroke of 5.5 inches.

According to the contract, the engines were to develop on trial 6,900 I.H.P. with a consumption of 1.45 pounds per I.H.P. If the I.H.P. rose to 7,890, the coal per I.H.P. might be increased to 1.52 pounds.

On May 26, the official trial was made off Dantzig, all five of the main boilers being used. The mean I.H.P. developed was about 7,930, and the coal consumption, 1.42 pounds per I.H.P. per hour. The mean speed was 16.5 knots, and the maximum, with 89 revolutions per minute, 17.5 knots.

On the first voyage, with an average I.H.P. of about 5,900, the coal consumption was 1.35 pounds per I.H.P.

The *Bremen* is equipped with sixteen electric cranes, in place of winches, eight on each side. Four of these have a capacity of about 6,600 pounds, with a hoisting speed of 60 feet per minute, and four, about 3,300 pounds at a speed of 120 feet per minute. The total swing of each crane outboard is 20.5 feet, and the movement of the jib, 13 feet per second. Current for running these cranes and for the lighting of the vessel is supplied by two

direct-connected dynamos in the after part of each engine room. Each dynamo is driven by a triple expansion Schichau engine and delivers 75 kilowatts at 105 volts when running at 210 revolutions per minute. One dynamo is used for lighting, two for the cranes and the fourth is held in reserve.

The cranes, motor and controlling mechanism are mounted upon a circular iron platform which revolves upon a pivot. This is turned by a motor of 7 horse power, running at 700 revolutions per minute, direct-coupled to a worm gear, which in turn meshes in a gearing bolted to the deck. The loads are raised by a 25-horse power series motor, running at a speed of 900 revolutions, and driving a special worm gear meshing into the gear of the drum. On the gear end of the drum shaft is fitted a winch head. The controllers resemble a double street car controller about two feet high. They are fitted with magnetic blow-out, any spark being immediately extinguished in a magnetic field. The contact cylinders are operated by a special mechanism, actuated by a simple handle or lever, the movements of which correspond to the movements of the load. Raising the handle raises the load, depressing the handle lowers the load, and movement of the crane to the right or left is obtained by corresponding movements at the lever. Raising and swinging movements can be effected simultaneously. Motors and controllers are water and dust tight, but the cases of both can readily be opened when necessary. To give a more perfect control, both motors are provided with band brakes operated by the foot. These brakes are attached to an extension of the motor shaft. The cranes are absolutely noiseless in their operation.

Miami.—This steel twin screw steamer, built by the Wm. Cramp & Sons' Ship and Engine Building Co., Philadelphia, for the Florida East Coast R. R. Co., was successfully launched on October 23. The following particulars are from "The Marine Journal," New York.

The length between perpendiculars is 240 feet; beam, 40 feet; depth, 23 feet; speed on trial, to be 16 knots. The vessel will run from Miami, Florida, to Nassau, Bahama Islands. She has three decks, and two tiers of state rooms finished in white

mahogany, and can carry 120 passengers comfortably. The galley is in the stern of the vessel, and is so arranged that the fumes of cooking cannot permeate the ship.

The machinery consists of two independent, three-cylinder, triple expansion engines, which drive two manganese bronze, three-bladed propellers. Each engine has independent air and circulating pumps. Steam is supplied by four cylindrical return tube boilers. There are two complete installations of electric machinery. Each stateroom has its own light as well as an electric fan. On top of the pilot house is an adjustable 4,000-candle power search light. The vessel will be schooner-rigged and have two smoke pipes.

The contract was awarded on June 28, 1897, the keel laid, July 3, and the first frames erected, July 31.

Senator.—This steel passenger and freight steamer is building for the Pacific Coast Steamship Co. by the Union Iron Works, San Francisco. The following particulars are from "Seaboard," New York.

The length over all will be 288 feet; beam, 38 feet 2 inches; depth, 21 feet; draught of water with 1,500 tons of cargo, estimated to be not over 15 feet. There will be accommodation for fifty first and fifty second class passengers. The main saloons and dining room will be handsomely decorated and furnished, and electric lighting and all modern improvements will be introduced. As the route of this steamer lies partly in the tropics, the design has been made with a view to insure perfect ventilation throughout. There will be a cold storage room with a capacity of forty tons.

The motive power will consist of a triple expansion engine, with cylinders 23, 26 and 60 inches in diameter, the stroke being 36 inches. When running at 125 revolutions per minute, the I.H.P. is to be 1850. Scotch boilers, with a working pressure of 160 pounds to the square inch, will be installed.

Juniata.—This single screw steamer, built by the Harlan & Hollingsworth Co., and described on page 621 of the August number, was successfully launched on September 2.

Cymric.—Another of the large, twin screw, freight and cattle

steamers, built by Messrs. Harland & Wolff, Belfast, for the White Star Line, was successfully launched on October 12.

The length is 600 feet; beam, 64 feet; depth, 42 feet; gross tonnage, about 12,300 tons; and displacement, about 23,000 tons.

The twin screw engines will be of the quadruple expansion type, and the working pressure in boilers, 200 pounds per square inch.

Pretoria.—This large freight and passenger steamer, referred to on page 862 of Volume VIII, was built by Messrs. Blohm & Voss, Hamburg, for the Hamburg-American Steam Navigation Co., and successfully launched on October 9. She is a sister vessel of the *Pennsylvania*, described on page 439 of the May number.

Minneapolis and **St. Paul.**—These two lake steamers are building by the Chicago Shipbuilding Co. for the Lower Lakes Steamship Co. The length will be 254.5 feet over all, and about 240 feet on keel; beam, 42 feet; depth, 26 feet; carrying capacity, about 2,800 tons net on a draught of 14 feet.

The triple expansion engine will have cylinders 17, 29 and 47 inches in diameter, the stroke being 36 inches. The two cylindrical boilers will be 11 feet in diameter and 12 feet long, the working pressure being 170 pounds per square inch. The boilers are building by the Cleveland Shipbuilding Co.

The estimated cost of each vessel is $125,000.

Indus.—This twin screw passenger steamer, built for the Messageries Maritimes Co., was successfully launched at La Ciotat on August 29. The following particulars are from "Le Yacht," Paris.

The length over all is 464.8 feet, and between perpendiculars, 442.9 feet; beam, 50.85 feet; depth, 36.09 feet; displacement, 6,338.25 tons. The vessel was built under the requirements governing auxiliary cruisers, and will carry, in time of war, six 5.51-inch and several 1.46-inch rapid fire guns.

The twin screw engines will be of the triple expansion type and develop 7,100 I.H.P., giving the vessel a speed of 18.5 knots.

Avon.—This twin screw passenger steamer, built by Messrs.

Wigham, Richardson & Co., for the Carron Company for the London & Grangemouth Service, made a special trial on the Thames in the early part of June. The Director of Naval Construction and the Engineer-in-Chief of the British Navy were on board to witness the trial. The following particulars are from "The Practical Engineer," London.

The length of the vessel is 290 feet. Bilge keels are fitted. The first class staterooms are amidship, forward of the boiler compartments and on a level with the poop, and the second class rooms, aft under the poop. The first class dining saloon extends the whole width of the vessel, with a music room at its forward end.

The triple expansion, four-cylinder engines are of the Schlick, Tweedy and Yarrow balanced type, with cylinders 23.5, 38 and (2) 43 inches in diameter, the stroke being 36 inches. The sequence of valves and cylinders, beginning forward, is as follows. L.P. slide valve, L.P. cylinder, H.P. cylinder, H.P. piston valve, I.P. piston valve, I.P. cylinder, L.P. cylinder and L.P. slide valve.

There are four single-ended cylindrical boilers fitted with Howden's forced draft system.

The propellers are 12 feet 8 inches in diameter. Brown's automatic gear, for stopping the engines in case a safe speed is exceeded, and his steering gear are fitted.

On the trial, the steam pressure was 180 pounds per square inch; vacuum, 25 inches; revolutions per minute, 128; I.H.P., 2,637; speed, 17.5 knots. There was no vibration.

Reindeer and **Roebuck.**—The trial results of these two steamers, built by the Naval Construction Company of Messrs. Vickers, Sons & Co., Barrow, for the Great Western Railway Co., were given on page 626 of the August JOURNAL. The following additional description of the hulls, machinery and trials is from "Engineering," London.

The length is 280 feet; beam, 34 feet 4 inches; depth, 16 feet; gross tonnage, 1,300, and displacement, 1,740 tons. There are ten water tight bulkheads and three complete decks, lower, main and promenade, with water ballast tanks for trimming purposes.

The promenade deck extends fore and aft, except that there is a well aft in connection with the cargo hatchway. The six boats are carried on supports above the promenade deck. The first class accommodation is fitted amidships, forward of the boiler compartments, and berths are provided for 150 passengers. On the promenade deck are the ladies' sitting room, the smoking saloon and the first class entrance, with broad staircase to the dining saloon and ladies' retiring room on the main deck, and to the state rooms and sleeping cabins on the lower deck. The dining saloon is the full width of the ship, capable of seating about 50 persons comfortably, and is handsomely fitted up. The saloon is lighted by large side ports, and a large dome skylight rises in the center to the top of the promenade deck house. Sleeping accommodation is provided for 76 second class passengers on the main and lower decks aft. The lower deck is reserved for the ladies' sleeping cabin, while on the main deck are the dining saloon, pantry and lavatories. The firemen are berthed in a separate compartment on the lower deck aft; officers, on the main deck abaft the engines; the crew, on the lower deck forward; and on the main deck forward, the petty officers, who have separate cabins. The electric light installation is in duplicate.

The twin screw triple expansion engines have cylinders 23, 36 and 56 inches in diameter, the stroke being 33 inches. The three cranks are set at an angle of 120 degrees with each other. The cylinders are separate castings bolted together. The H.P. and I.P. cylinders are fitted with separate cast iron liners. Piston valves are fitted to the H.P. and I. P., and double-ported flat valves with balance piston, to the L. P. cylinders, and all are worked by the usual double eccentric link motion. The reversing engines are of the direct-acting steam and hydraulic type. Slot levers on the reversing shaft enable the cut-off in the different cylinders to be adjusted independently. The front columns, adjacent to the center of the ship, are of cast iron and of the ordinary split type, with separate guide faces. The bed plates are of cast iron with flat bottom. The shafting throughout is of mild steel, finished bright. One air pump, 20 inches in diam-

eter by 16.5 inches stroke, is fitted to each engine, and driven by levers from the H.P. crosshead. The condensers are cylindrical, of cast iron, and placed in the wings of the ship. The tubes are of brass, $\frac{5}{8}$ inch in external diameter, with a total condensing surface of 8,000 square feet. The water is circulated through the tubes by a centrifugal pump for each engine. These pumps can be connected to either condenser. Two Weir direct-acting feed pumps, with automatic control gear, are fitted in the engine room. A filter is fitted between the feed pump and the boilers, and a Weir feed water heater is installed. The propellers are solid, four-bladed, and of manganese bronze.

There are two double-ended cylindrical boilers, each 15 feet 2 inches in diameter and 20 feet long, and having six corrugated furnaces. The total heating surface is 10,838, and the grate surface, 250 square feet. The working pressure is 175 pounds per square inch. Howden's forced draft system is applied to the boilers; two fans supply the air, each driven by a Belliss improved, closed type, steam engine with forced lubrication.

The speed trials took place on the Clyde, and consisted of four runs between the Clock and Cumbrae lights, a distance of about 13.5 nautical miles, the mean results being as follows. The engines ran at full power for nearly six hours, and worked well.

	Roebuck.	*Reindeer.*
Steam pressure, pounds per square inch	169.	173.9
Vacuum, inches	26.25	26.6
Revolutions per minute	160.07	163.26
Second mean speed, knots	20.217	20.52

Victoria.—This steamer was launched from the shipbuilding yard of Messrs. Furness, Withy & Co., West Hartlepool, on July 31. She was built for the Wilsons and Furness-Leyland Line, and is intended for their Boston and New York passenger, cattle and cargo trade. The following particulars are from "The Engineer," London.

Length over all, 490 feet; beam, extreme, 52.25 feet; depth, moulded, 34.5 feet; deadweight carrying capacity, about 8,450, and measurement capacity, about 11,900 tons. She has three complete steel decks, and a shade deck above.

The main engines, built by Messrs. Thomas Richardson and Sons, have cylinders 32, 54 and 90 inches in diameter, the stroke being 66 inches. The designed I.H.P. is about 5,000. The H.P. cylinder is fitted with a piston valve, and the I.P. and L.P. cylinders, with double-ported slide valves, the cylinder supports consisting of massive cast iron divided columns. The circulating pump is independent, and the air pump is of Edwards' design. The condenser is circular and made of steel plate. The shafting is of steel.

There are two double and two single-ended boilers, the latter being in the center and arranged back to back, all fitted with Morison's suspension furnaces and Henderson's rocking grate bars. The working pressure will be 190 pounds per square inch.

An electric light plant, on the single wire system, for 120 16-candle power lamps, is installed. The dynamo is driven by two single-cylinder engines, with cylinders 9 inches in diameter and a stroke of 7 inches. With a steam pressure of 95 pounds per square inch, they will run at 275 revolutions per minute.

Alexandra.—A sister vessel of the *Victoria*, described above, built by Messrs. A. Stephen & Sons, Linthouse, for the same company, was launched on August 3.

Kastalia.—This single screw steamer, built by the London & Glasgow Engineering & Shipbuilding Co., Govan, for Messrs. Donaldson Brothers, Glasgow, was successfully launched on June 2, and made her trial on July 6. The following particulars are from "Industries & Iron," London.

The length is 377 feet; beam, 46 feet 7 inches; depth, molded, 29.5 feet; gross tonnage, 4,300 tons; dead weight carrying capacity, 6,200 tons. The spar and main decks are arranged to carry cattle, and the after 'tween decks are divided into four refrigerating chambers. The double bottom runs the whole length of the vessel. Abaft the engine room, there is a compartment tank capable of holding about 650 tons of water, and the forward and after peaks are also fitted for water ballast. Steam ventilating fans are fitted for the lower decks.

The triple expansion engine has cylinders 27, 44 and 72 inches in diameter, the stroke being 48 inches. The condenser is at

the back of the engine, and the air and circulating pumps are worked by levers from the L.P. crosshead. The feed and bilge pumps are worked by the same gear. A Weir evaporator is fitted in the engine room, and a feed water filter and heater are installed. The two main boilers are single-ended, with three furnaces each, and are 15 feet 4 inches in diameter and 11.75 feet long. Howden's forced draft system is fitted. An auxiliary boiler is also installed in the fire room. Steam steering gear, nine steam winches, and a steam capstan windlass are fitted.

On the trial over the measured mile at Skelmorlie, the vessel made 12 knots, as a mean of four runs.

New Lake Steamers.—The Cleveland Shipbuilding Co. will build during the coming winter two steamers, and the American Steel Barge Co., a whale back steamer, all to have Babcock & Wilcox water tube boilers and quadruple expansion engines.

One of the Cleveland Co.'s steamers will be of 6,000 tons' capacity, and will be built for the Zenith Transit Co., and the other, for the Cleveland Cliffs Iron Co. The engine of each vessel, also to be built by the Cleveland Co., will have cylinders 17, 26, 39 and 60 inches in diameter, and a stroke of 40 inches, the I.H.P. being about 2,000. The boilers will be the same in each vessel, and the working pressure, 250 pounds per square inch.

The American Steel Barge Co.'s steamer will be, when completed, the largest whale back built to date, and will differ from the prevailing practice in this type of vessel by having a straight stem instead of a spoon bow. It is found that with the spoon bow vessels swing around too easily for safe steering, and that frequent collisions result with other vessels and with docks. Hence, the ordinary fore foot will be constructed. The engine will have cylinders 19, 28.5, 43.5 and 66 inches in diameter, the stroke being 40 inches. The I.H.P. will be about 2,200, and the working pressure, as above.

YACHTS.

Niagara II.—This twin screw yacht is building by the Harlan & Hollingsworth Co., Wilmington, Del., for Mr. Howard Gould of New York. The following particulars are from the "American Shipbuilder," New York.

Length over all, 270, and on load water line, 245 feet; beam, 36 feet; depth of hold, from spar deck, 28, and from main deck, 20 feet; freeboard amidship, 13, and at bow, 18 feet; tonnage, 1,900. The steel hull will have a double bottom and three decks, and will be built to the requirements of the British Lloyd and the American association. The vessel is to be delivered by April 15, 1898, the contract speed being 14 knots. On the upper, or spar deck, there will be a continuous house of steel, 100 feet long and 16 feet wide, to be covered with mahogany or teak. In the forward part of this house will be the chart room, containing duplicate steam steering gear for use in bad weather, and the captain's quarters. The social hall, 32 feet long and the full width of the house, follows aft; adjoining will be the smoking room, 12 by 16 feet; a passageway from it along the engine space on the port side, which is to be glass-enclosed, leads to the owner's room on this deck, of the same size as the smoking room. From the owner's quarters, the observation room, which is in the extreme after end of the deck house, is reached. This room will be for use particularly in rough weather. The sides are to be of glass, and the ends rounded, but will not meet; the after entrance being hung with heavy curtains, while the roof of the house will extend a short distance over it and be neatly finished. From the after end of the deck house to the taffrail there is a space of 45 feet. The bridge will extend from the forward end of the chart room aft to the smoke pipe.

From both ends of the social hall, there will be broad stairways, the forward one leading to the staterooms on the main deck—all accommodations being forward—and the after one to the library,

which opens into the dining saloon. The library, 22 by 12 feet, is on the starboard side; its after end will be fitted as a large armory, and will be enclosed with glass. The dining room is 24 feet long by 36 feet wide, the full width of the vessel, and will be handsomely furnished, while a fireplace of exquisite and appropriate design will add much to the spacious and cosey apartment. Domes in the sides of the social hall, ingeniously concealed from view within, will give sufficient light and additional ventilation to the dining saloon, and at the same time will permit of very effective and artistically-arranged electric lights. From a door on the starboard side of the dining saloon, the owner's suite is entered, including a bedroom, 16 by 16 feet, a dressing room, 7 by 10 feet, and a bath room, 5 by 10 feet. On the port side, directly opposite, is the largest guest's suite, the three rooms being similar in size to those of the owner. The finish and fittings of these six rooms will be rich and handsome. Four staterooms, each with a private bath, are forward, one a doctor's room; a photograph room, and a brushing room, together with linen and other lockers.

Going back to the library, there will be, opposite to it, a large butler's pantry; two connecting kitchens, one for the owner and guests and the other for the officers and crew; a laundry, a hospital room and a room for a valet. The quarters for the officers and crew are aft on this deck and are particularly commodious. They will have a recreation space of 40 feet by 36 feet, which will be lighted and ventilated from large square port holes, hooked back from above, thus giving them really a shaded open deck. The complement will be about 50 officers and men. The stairway from the social hall will continue to the lower deck, where there will be found three more guests' rooms, a servants' hall, rooms for the maids, trunk and general storage rooms. The plumbing work is to be of the most modern description. Hot and cold fresh and salt water will be found in all bathrooms.

The engines will be triple expansion, with cylinders 18, 28 and 45 inches in diameter, and a stroke of 30 inches. There will be three cylindrical boilers with a working pressure of 160 pounds per square inch.

The yacht will be lighted throughout by electricity, two dynamos being supplied; a large storage battery will be fitted. She will be bark-rigged and carry eight boats: one 15-foot steam launch, one 24-foot naphtha launch, two gigs, two dingheys and two lifeboats.

Annett.—This steel yacht was built by Messrs. D. J. Dunlop & Co., Port Glasgow, for Mr. Chas. Canaple, Marseilles. The following particulars are from "Engineering," London.

The length on the water line is 88 feet; beam, 14.5 feet; depth, molded, 10 feet; tonnage, Thames yacht measurement, 87. The rig is that of a two-masted schooner, and there is one smoke pipe. The accommodation for the size of the vessel is large and well-arranged, the main saloon and sleeping cabins being all forward of the machinery, with a large deck saloon and companion way above. The officers and men are berthed aft. The cabins and all the internal fittings are handsomely fitted up in hard wood, oak being the principal wood used.

From the conditions that had to be adhered to with regard to weight of machinery and heating surface of boiler, it was decided to adopt a light type of engine instead of the usual design; and the result obtained, both on trial and since then, have fully confirmed the builders' decision. The engines have cylinders 9, 15 and 24 inches in diameter, and a stroke of 15 inches. The high pressure and intermediate pressure cylinders are fitted with piston valves, while the low pressure has one flat "Trick" valve. All three cylinders are cast together, but so arranged that each part can easily be got at. The exhaust passage to the intermediate pressure from the high pressure cylinder is part of the casting of the high pressure barrel; that to the low pressure from the intermediate being a copper external pipe, as usual. The cylinders are supported from the sole plate by eight turned steel columns well braced together, the two center ones at the back of the engines carrying the bearings for the pump levers. The sole plate is of cast iron, and has four bearings carrying the crankshaft. The shafting is of Siemens-Martin steel throughout, the crankshaft being built-up. All crankpins, main bearings and guides have white metal bearing surfaces. The valve motion is of the

double bar link type, with large wearing surfaces, and is reversed by means of a wheel and screw.

The air and circulating pumps, worked by the engines in the usual way by means of levers, are each 8 inches in diameter by 7.5 inches stroke, single-acting, without foot valves. All of the pumps and connections are made of brass or gun metal, the pipes connecting to the condenser being of copper. The condenser shell is of galvanized steel, the heads being of cast iron. The tubes are tinned, and are $\frac{5}{8}$ inch in exterior diameter. The whole condenser occupies little space, and is supported from the framing of the ship.

The boiler is 9.75 feet in diameter and 8 feet long, with two suspension furnaces, 2 feet 8 inches in smallest internal diameter. There are 144 tubes, 5 feet 7 inches long between tube plates, and 3 inches in external diameter. The total heating surface is 781, and the grate surface, 27.5 square feet, the working pressure being 170 pounds per square inch.

The time which elapsed between the launching of the vessel and the official trial trip with owner on board, was only 33 working hours. As the mean of six runs on the measured mile, a speed of 10.8 knots was obtained, with a mean indicated horse power of fully 250. A maximum horse power of 260 was obtained with the engines making 184 revolutions per minute. During the whole of the trials the engines worked well, and the absence of vibration was most marked. The weight of machinery with steam up was 32 tons, that of the engines and condenser alone being $5\frac{3}{4}$ tons.

Alcedo.—This yacht, described on page 446 of the May number, has a vertical, twin air pump of the Blake type.

———.—This twin screw yacht, to be built by Messrs. A. & J. Inglis, Pointhouse, Scotland, for Mr. Jas. G. Bennett, will be similar to the *Varuna*, described on page 210 of the February number. The following particulars are from "Seabord," New York.

The length will be 300 feet over all, and 260 feet on the water line; beam, 35 feet; tonnage, Thames yacht measurement, 1,500; speed, 17 knots. She will be built of steel, flush-plated, with

continuous edge strips fitted in the side. The yacht will be lighted by electricity and fitted with all modern improvements. On the promenade deck will be a wheelhouse and chart room. On the main deck forward will be a room 21 feet long and 13 feet wide. Aft of the smokestack is another room 23 feet long and 13 feet wide, to be used as a breakfast and smoking room.

The twin screw, triple, expansion engines will have cylinders 22.5, 38 and 40 inches in diameter, the stroke being 42 inches.

BOOK REVIEW.

CASSIER'S MAGAZINE, Marine Number, August, 1897. Published by the Cassier Magazine Co., New York.

This special number of this magazine contains 300 pages of valuable and well-chosen information on various subjects interesting to ship and engine designers, builders and users. The seventeen different papers are written by well-known experts of Great Britain and our own country, and are supplemented by numerous and excellent illustrations.

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Page 532, sixth line from bottom, for *fitted* read *pitted.*
Page 616, eighth line from top, for *3.73* read *37.3.*

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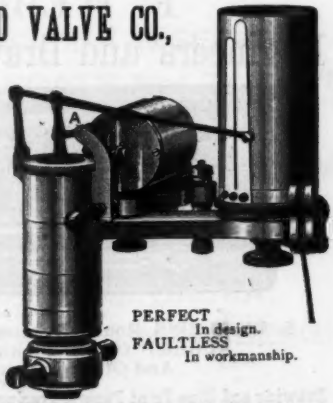

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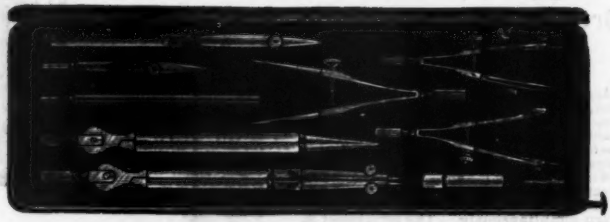

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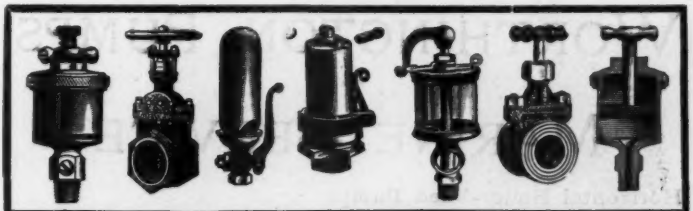

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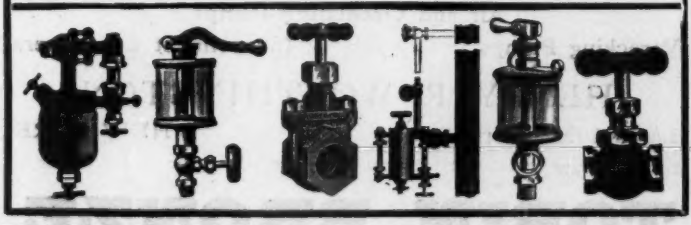

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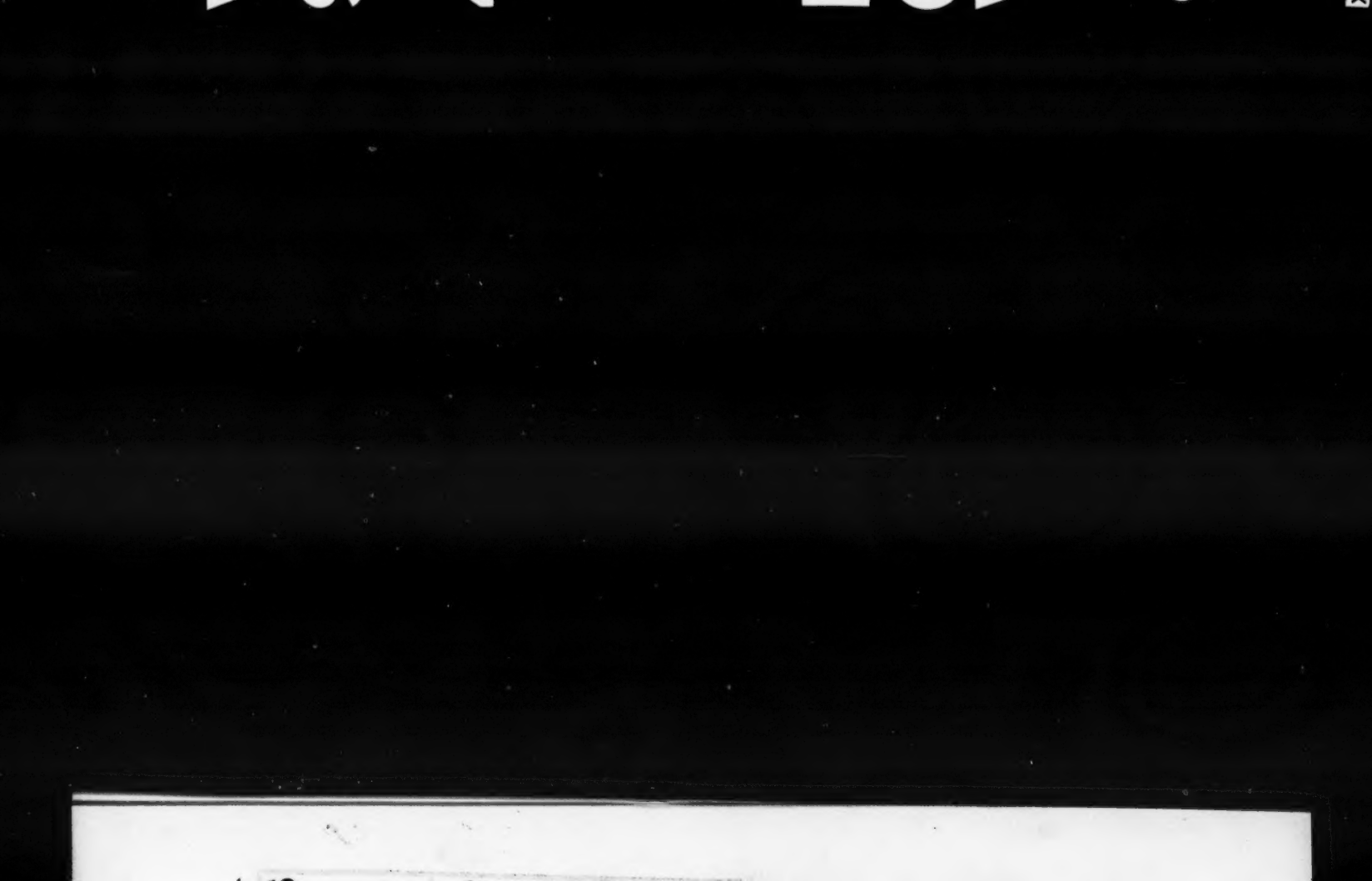
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